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REPORT OF THE

FOREST PRODUCTS RESEARCH BOARD

FOR THE YEAR 1936

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DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

REPORT OF THE FOREST PRODUCTS RESEARCH BOARD

With the Report of the Director of Forest Products Research FOR THE YEAR 1936

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REPORT OF THE FOREST PRODUCTS RESEARCH BOARD FOR THE YEAR 1936

To the Lords of the Committee of the Privy Council for Scientific and Industrial Research

MAY IT PLEASE YOUR LORDSHIPS,

WE, the Forest Products Research Board, beg leave to present our Report for the Year 1936.

The period covered by the Report has been of special importance to the Board as it included a survey of the work and policy of the Forest Products Research Laboratory, carried out on behalf of the Department of Scientific and Industrial Research by a Committee appointed for the purpose. Inspections of this nature are held periodically by the Department on the various activities under their control, and the Board welcomed the opportunity thereby afforded to review the present position and to adjust future policy. At a meeting of the Board held on Friday, 31st January, 1936, at the offices of the Department a Memorandum on the work of the Laboratory which had been prepared for submission to the special Reviewing Committee was fully considered and the views set forth in the document were approved by the Board. At the same meeting, memoranda on the International Botanical Conference held in Amsterdam in September, 1935, and on the Imperial Forestry Conference held in South Africa in September and October, 1935, were discussed, a progress report on the work of box-testing at the Laboratory was received, and the steps which had been taken to implement the scheme of investigations into conditions of attack on timbers by marine borers were also considered.

Throughout the year the Board was in close touch with the Reviewing Committee set up by the Department and the suggestions of the Committee were submitted to the Board for opinion at a meeting held at the Forest Products Research Laboratory, Princes Risborough, on Tuesday, 27th October. The Board's comments were subsequently laid before the Advisory Council for Scientific and Industrial Research, and the Board desires to take this opportunity of expressing its thanks for the helpful advice received in the course of the survey and for constructive suggestions which will find expression in the future policy of the Forest Products Research Laboratory.

At the October meeting a proposal that the Director should attend the Northern Timber Conference at Stockholm in the summer of 1937 was considered and the Board agreed that his attendance at the Conference was desirable. A proposal for the extension of

the research programme, submitted by the Director of Civil Aviation, New Delhi, was examined, and it was decided that the work involved in the proposal could not be given such priority as would bring it within the present programme of research recommended by the Board. The minutes of the Wood Preservation Committee were presented and approved.

The Board is pleased to note that there is evidence to indicate that suggestions emanating from the Forest Products Research Laboratory concerning the necessity of establishing more uniform and rigid grading rules for timber are being received with interest both in this country and in the timber exporting countries of Northern Europe, and views with satisfaction the prospect of the sympathetic consideration of these suggestions by exporters abroad and importers in Great Britain.

J. C. IRVINE
Chairman

July, 1937.

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH,
16 Old Queen Street,
Westminster, S.W.1.

REPORT OF THE DIRECTOR OF FOREST PRODUCTS RESEARCH FOR THE YEAR 1936

I. GENERAL

Introduction

The work which has been in progress under the various projects included in the programme of research of the Forest Products Research Laboratory for the year 1936 is summarised in this report. The results of investigations which have been completed are published separately, and details of the publications are given in Appendix III. Activities undertaken in co-operation with other bodies or with the object of giving publicity to the work of the Laboratory and the facilities which it offers for the solving of problems arising from

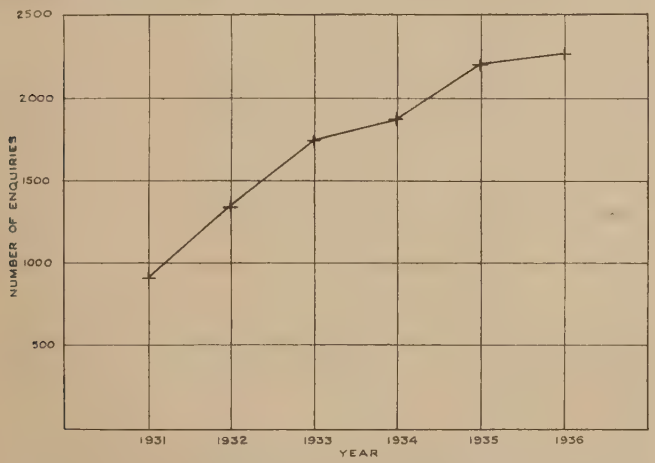

FIG. 1.—*Increase in the Number of Enquiries received during* 1931–1936.

the conversion and seasoning of timber and the manufacture of wooden goods are mentioned. Particulars of the tests carried out on timbers from various parts of the Empire overseas and of certain other work undertaken for the Dominions will be found in Appendix II.

The general progress of work during 1936 has been satisfactory. Wood-using industries have made more use of the services of the Laboratory, and there have been many applications for assistance and information. The annual increase in the number of enquiries during the last six years is shown in Fig. 1. The varied nature of

the enquiries indicates a growing appreciation of the value of scientific research in achieving economic production. It is gratifying to be able to report that architects have recently shown greater interest in the work of the Laboratroy than has been the case in the past.

In the course of the investigations under one or other of the projects alluded to, instances of abnormal behaviour in test pieces are frequently met with. It is essential that such behaviour should be critically examined with a view to discovering the causes, and it sometimes happens that new lines of research are opened up from such examination. Instances of this kind, by no means rare, demonstrate the limitations of the present knowledge of wood, and the urgent need for the further investigation of its chemical and physical properties.

The Summer School and other Educational Activities

In the summer of 1935 it was decided to organize a course of intensive instruction lasting for a week, to give timber merchants and users a wider knowledge of timber than is procurable at any of the technical institutions. The experiment met with such success and the demand for its repetition was so insistent, that it was decided to arrange a similar course in the late summer of 1936. Following the appearance of the notice of this course in trade and technical journals, so many applications were received that it was decided to increase the number of students to be accepted by 50 per cent. In spite of this, however, it was found quite impossible to accommodate all who wished to attend. The applicants included principals and departmental managers of industrial concerns, timber salesmen, estate agents, instructors in technical colleges and one architect. The comments made by technical and trade journals and individuals testified to the appreciation and the value of the instruction given, and to the need for continuing this work. The Laboratory has benefited from the direct contact with the students who attended, and it is obvious that they have helped in giving publicity to the work which is being done and its use to industry. In the course of the year numerous lectures have been given by officers of the Laboratory in various parts of the country, including Scotland. Requests for such lectures are increasing in number, a sure indication of the growing appreciation of the value of research work to the industry, the changing conditions of which are a feature of the present day.

Several papers have been prepared and read before learned societies, including one on the protection of wood by means of antiseptics, and a second on chemical reactions induced by wood-destroying fungi at the Second International Congress for Microbiology, which met in London in July.

The Laboratory was requested by the Director of Forests, Nigeria, to supply information on research in progress in Europe

on timber insects, together with references to literature and any other data available on the subject in general.

During 1936 the experimental work on wood-boring insects was continued upon the same lines as previously, and no new investigations were started. A considerable amount of time was spent in writing up the results of past experiments in order to bring the published records up-to-date. One general paper was published upon the various insects which attack home-grown oak[1] and, in addition, a short account was given at a meeting of the British Wood Preserving Association of types of insect damage in western red cedar.

The demand for articles for publication in technical and trade journals and for the publications of the Laboratory has been maintained.

[1] FISHER, R. C. Insects attacking the Timber of English Oak. *Forestry*, 1936, **10**, 47–57.

Ninth Congress of the International Union of Forest Research Organizations

The Ninth Congress of the International Union of Forest Research Organizations was held at Sopron in August and September, 1936, and the Laboratory was represented by the Director of Forest Products Research. The papers by the various delegates illustrated the problems engaging the attention of the organizations represented, and the occasion offered opportunities for unofficial exchanges of opinion and for making useful contacts. The Director was able to visit some of the continental research institutions in the course of his stay.

Second International Forestry Conference

The Second International Forestry Conference was held at Budapest in September, 1936, and was attended by the Director of Forest Products Research.

Collection of Wood Specimens

New specimens of timbers from all parts of the world, to the number of well over a thousand, have been added to the Laboratory's working collection. Many of the older specimens which were either unrepresentative or of doubtful authenticity have been replaced, and the value of the collection for reference purposes has been considerably improved. Collections have been received from Argentina (per the Imperial Forestry Institute), Australia, British Guiana, the Federated Malay States, Kenya, Sarawak, Switzerland, the U.S.S.R., the School of Estate Management, Cambridge University, and the Imperial College of Science and Technology, and a large number of microscope slides from the Imperial Forestry Institute. It is of interest to record that on 31st December, 1936,

the number of catalogued specimens exceeded 10,000, but the representative nature of the collection is better indicated by the number of species, which amounted to 3,835, over 500 of which were added during the year.

The exhibit collection of specimen boards displayed in the corridors of the Administrative Building now comprises more than 250 selected boards, including most of the important home-grown and Empire timbers.

Collection of Wood-boring Insects

The preparation of a reference collection of beetles of the families Scolytidæ and Platypodidæ, responsible for pinhole damage to timber, particularly from the tropical parts of the Empire, has been continued. The species have been identified by Dr. G. K. Blair of the British Museum (Natural History), to whom thanks are due for his willing co-operation. During the year, a collection of insects responsible for this type of defect in British Guiana timbers was forwarded by the Forest Department for examination and report.

Collection of Fungi

Further additions have been made to the collections of sporophores of wood-rotting fungi and of typical timber rots. The number of species maintained in pure culture has also been increased, and now includes 235 species of wood-destroying fungi as well as a number of staining organisms. In the case of some of the more important fungi, several different isolations are kept.

Exhibits

The value of exhibits of the right type in bringing to the notice of architects, builders, municipal engineers, and other interested authorities, the work and services of the Laboratory cannot be over-estimated. Exhibitions intended to reach the general public are of little value in this respect, but exhibitions of a more technical nature, such as those in which the Laboratory participated during the past year, have enabled many valuable contacts to be made, and their usefulness is reflected in the number of enquiries which are directly traceable to them.

Three major exhibits of this type were staged in 1936—at the Building Trades Exhibition, Olympia, at the Building Research exhibit held at the Merchant Venturers' Technical College, Bristol, and at the Conference of Municipal and County Engineers held in the Dome, Brighton, in June. The last was arranged at the invitation of the Timber Development Association, and during the period of the exhibition over one thousand seven hundred engineers saw the exhibit, and had an opportunity of discussing problems connected with the use of timber.

II. PROGRAMME OF RESEARCH

Tree Growth and Timber Quality

Studies in wood structure may be appropriately related both to the growth of the tree and to the quality of the timber. The structure of wood is an important factor in determining the quality of timber for industrial purposes and is greatly influenced by the conditions under which the tree is grown. Such studies are primarily concerned with home-grown timbers, particularly those which are of present importance in British forestry practice. The various species of commercial timber trees differ in the way in which their useful properties are affected by variations in growth conditions. Common English oak is an outstanding example of a timber the quality of which is primarily determined by conditions which affect the gross structural features of the wood. The texture and working properties of the wood, its strength, density and stability under varying conditions of atmospheric humidity are closely connected with the growth of the tree. A comprehensive investigation of this species has enabled broad conclusions to be drawn regarding the influence of growth conditions on quality, and these have been published.[1] During 1936 similar investigations have been continued on home-grown ash, beech and Sitka spruce. In the last-named species the effect of certain structural features on the maximum crushing strength has been further investigated. The results are presumably applicable, in part at least, to softwood timbers generally. It has been found that the larger tracheids which are normally developed towards the outside of the tree are associated with somewhat higher strength values than can be accounted for by the general specific gravity and ring-width relations. Such wood may be regarded as having a higher mechanical efficiency. Whereas the majority of the specimens examined had growth rings of the usual spruce type, namely, a consistently narrow summerwood zone, a springwood zone of varying width and a gradual transition from springwood to summerwood, a number contained growth rings more like those of the hard pines, being characterized by a more sharply defined, or higher proportion of summerwood tissue. Specimens of this latter type were found to be more efficient from the strength point of view. The occurrence of resin ducts, which are rather less well developed in Sitka spruce than in some other resinous softwoods, has been found to have no appreciable effect on the strength of the wood. Some evidence which suggests the existence of a general relation in this species between the inclination of the micelles in the secondary walls and the resistance of the wood to crushing has been obtained. The micellar angle in the denser tissues of the growth ring appears to be especially significant in this connection.

[1] Rendle, B. J. The Growth and Quality of English Oak. *Forestry*, 1936, **10**, 38–46.

The Influence of Climatic Factors on the Properties of Wood

The intensive investigation of home-grown hardwoods has shown that in certain cases some of their most important properties depend more on the physico-chemical nature of the cell wall than on the gross structural features of the wood. There are good reasons for concluding that the composition of the cell walls is largely influenced by the locality of growth. Continuing the study of ash and beech by the method developed for the former species, further evidence that the composition of the cell walls has an overruling influence on the strength of the timber has been obtained. As an example of the extreme influence of variations in cell wall composition a pair of beech test specimens matched for specific gravity and rate of growth gave values for maximum crushing strength in compression parallel to the grain of 2,400 and 5,200 lb. per square inch respectively. The results of an investigation on home-grown beech from seven different localities have been published.[1]

[1] CLARKE, S. H. The Influence of Cell-wall Composition on the Physical Properties of Beech Wood (*Fagus sylvatica*). *Forestry*, 1936, **10**, 143–148.

Temperate and Tropical Hardwoods

A comparison has been made of selected hardwood species, similar in average specific gravity, but showing extreme differences in mechanical properties. The results of a large number of mechanical tests carried out in various timber-testing laboratories show that tropical timbers are generally weaker in impact bending (a measure of toughness) and stronger in compression parallel to the grain than are temperate timbers of similar density. Both these strength properties are fairly closely related to specific gravity and, therefore, indirectly to each other, but statistical analysis shows that, apart from this indirect positive relation, strength in impact and in compression parallel to the grain are inversely related. Such a condition might well be due to some factor influencing the strength properties in different directions, and the reaction of tropical and temperate timbers to certain microstaining reagents clearly indicates that these two types of growth conditions influence the properties of the timber through the composition of the cell walls.

To eliminate the possibility of these differences being due to hereditary rather than climatic factors, several genera with both tropical and temperate representatives have been investigated. It has been found that the staining reaction is sufficient to distinguish the tropical from the temperate species in every case.

These results are of special interest as indicating one important way in which climatic factors affect the properties of timber. No tropical timber of outstanding toughness has yet been discovered, and it would now appear possible that no such timber will be found

to exist. A full report of this investigation is being prepared for publication.

Natural Compression Failures in Timber

During the past year a study[1] has been made of the defect variously known by the names thunder-shake, heart-shake, cross-break, etc., which is liable to affect a number of well-known commercial timber trees. The defect takes the form of irregular zig-zag fractures running across the grain at intervals of a few inches to several feet apart, and varying in intensity from a slight buckling of the cell wall to a complete cross fracture of the fibres. In all cases examined the distortion of the fibres is of the nature of a compression failure such as is induced by subjecting timber to longitudinal compression (parallel to the grain) or by a bending moment. The various theories as to the origin of these failures have been critically examined, and it has been concluded that they are probably due to wind action or some other external force bending the tree trunk during the comparatively early years of its growth.

[1] Rendle, B. J. Natural Compression Failures in Timber. *Emp. For. J.* 1936, **15,** 182–189.

Structural Reasons for the Warping of East African Pencil Cedar

The so-called compression wood or *rotholz*, which is commonly formed on the leeward side of conifer stems and on the under side of branches, differs from normal wood notably as regards its hardness, density and longitudinal shrinkage. In the course of investigations of African pencil cedar (*Juniperus procera*) it has been established that the abnormal warping that occurs in a proportion of pencils is largely due to the presence of tissue similar in many respects to the compression wood of temperate softwoods.[1] Trees of different types of growth have accordingly been examined to see whether the presence of this abnormal tissue could be related to the growth irregularities often present in the trunk of this species. No direct relation has been found to exist between the shape of the stem and the presence of compression wood, such as would facilitate the elimination of faulty timber in the early stages of conversion. It should be possible, however, to reduce the proportion of warped pencils by rejecting defective pencil slats before manufacture.

[1] Phillips, E. W. J. The Occurrence of Compression Wood in East African Pencil Cedar. *Emp. For. J.*, 1937, **16,** 54–57.

The Classification of Commercial Timbers

For practical reasons it is desirable that the botanical classification of timbers should be correlated with their commercial classification, which is liable to be confused and misleading, especially in the case of new timbers. In recent years the commercial timbers of the family Dipterocarpaceæ have become increasingly important to the wood-using industries of this country. Broadly speaking, this family furnishes two distinct classes of timbers, the softer,

lighter woods, variously known as seraya, meranti, and lauan, which are extensively used, among other purposes, as substitutes for mahogany, and the heavier timbers such as gurjun and keruing, which are preferred for flooring and constructional purposes. There is evidence that some confusion regarding the various timbers of this family exists, and, therefore, two publications have been prepared summarising the chief points of resemblance and difference between the principal commercial varieties, and providing a key to their trade and vernacular names.[1] On similar lines the first draft of a publication dealing with commercial mahoganies and allied timbers has been prepared. A comprehensive report on teak has also been compiled from the mass of technical information available. Progress has also been made with a comparative study of the timbers of the Leguminosæ.

[1] Rendle, B. J., and Clarke, S. H. Seraya, Meranti and Lauan. *For. Prod. Res. Rec.*, 1936, No. **12.**

Clarke, S. H., Gurjun, Apitong, Keruing, Kapur and allied Timbers. *Loc. cit.*, 1937, No. **16.**

The Identification of Timbers

The Laboratory is called upon to identify a considerable number of specimens of timber in some shape or form. The majority of these are fairly well known, and can be identified without much trouble, but there is always a proportion of comparatively unfamiliar timbers the identification of which may present some difficulty. There are several excellent keys for identifying the timbers of particular countries, but the dichotomous system usually employed is only effective for a limited number of woods, and up to the present no comprehensive key to the commercial timbers of the world has been published. During the year a semi-mechanical universal key has been constructed, based on the Paramount system of sorting perforated cards, and sufficiently elastic to include an indefinite number of species. Nearly four hundred of the more important timbers have so far been incorporated, and the key is proving very satisfactory in use.

Statistical Methods

A thorough analysis was made of the data provided by a chemical and mechanical investigation on English ash, and all the variables studied were found to be closely related to position in tree and, consequently, to each other. The choice of the more important could, therefore, only be made by the use of statistical methods which provide numerical comparisons of such relationships. The analysis elicited the fact that of all the constituents studied the Cross and Bevan cellulose showed the closest relationship to maximum crushing strength, the latter being calculated as lb. per sq. inch of wood substance. The conclusions have been published.[1]

A similar investigation, but dealing with structural variables only, was made on Sitka spruce. When the maximum crushing

strength of this wood was calculated as lb. per sq. inch of wood substance there was no longer any significant relation of strength to specific gravity, as there would have been had the strength been calculated on the area of the block. This indicates that specific gravity is useful only as a measure of the amount of wood substance present. In the ash investigation, on the other hand, a significant relation of specific gravity to strength calculated in both ways was found, so that the two woods differ in this respect.

Other studies made with the aid of these methods include (*a*) fire resistance data on the effect of direction of penetration relative to the grain on the rate of flame penetration; (*b*) the differences in rotation of polarised light in certain acid and neutral solutions, and (*c*) the analysis of the results of tests on tomato cases.

The calculations necessary in statistical analysis are often lengthy and tedious so that any method of shortening them would make more extensive exploration of hypotheses possible. To this end experiments have been made, with the co-operation of H.M. Stationery Office, on the use of punched card methods, and some knowledge has been gained of the limits of useful application of these methods.

[1] Bamford, K. F., and van Rest, E. D. The Relationship between Chemical Composition and Mechanical Strength in the Wood of English Ash. *Biochem. J.*, 1936, **30**, 1849–1854.

Heat

During the year the technique of making thermal diffusivity measurements has been adapted to wet wood. Measurements so far made indicate that the diffusivity of wet wood is less than that of dry wood. This is contrary to the opinion which has been expressed from another Laboratory. It is known that the thermal conductivity of wood increases with increasing moisture, but it has been supposed that the specific heat of wood increases in the same proportion so that the diffusivity, which involves their quotient, remains the same. The specific heat above 25 per cent. moisture content has not been actually measured so that there is no experimental justification for this assumption. As an example the observed diffusivities of *Guarea cedrata* are given below.

Dependence of Thermal Diffusivity of Guarea cedrata *on Moisture Content*

Thermal diffusivities c.g.s. units $\times 10^4$

Approximate Moisture Content	Direction of heat flow		
	Longitudinal	Radial	Tangential
Green, 75 per cent.	15	10	11·2
Dry, 12 per cent.	28·9	—	19·4

In continuation of this work, pieces of beech are being conditioned to intermediate moisture contents. The results so far obtained indicate that, although the differences in diffusivity are not so large as in the case of *Guarea*, they also show a decrease with increase of moisture.

The calculated time for temperature rises under specified conditions will be considerably influenced by these differences in the coefficient of diffusivity.

Moisture Relations of Wood

Progress has been made by the Physics Section during the year under review in acquiring knowledge of the forces by which water is held in wood, and of the behaviour of wood under these forces. In last year's report an account was given of the way in which the molecular sorption of water had been distinguished from the capillary sorption by using as an indicator the change of concentration of a sugar solution when mixed with the wood flour[1], and it was pointed out that the provisional minimum value of 23 per cent. for Sitka spruce could not be accepted unless further investigation showed that the change in concentration, from which it was calculated, was permanent and would not change over long periods. This point has now been settled, as it has been found that the sorption remains constant over a period of months. Although this value of 23 per cent. is considerably higher than that given by other workers, independent evidence that it is substantially correct has also appeared [2] in the work on shrinkage mentioned below, since at low moisture contents the volume of the wood is principally controlled by molecular sorption. If the equation connecting these two latter quantities is used to calculate the sorption at zero shrinkage (that is at a saturated vapour pressure), a value of 26 per cent. is found for the molecular sorption.

The knowledge which has so far been gained on the proportions of water held by molecular and capillary forces at any vapour pressure may be summarised as follows for Sitka spruce :—

Starting from complete dryness, the water is held entirely by molecular forces up to about 30 per cent. relative vapour pressure (6 per cent. moisture content), at which point the capillary water first appears, and increases slowly until at about 80 per cent. relative vapour pressure (20 per cent. moisture content) it is sufficient to influence shrinkage and swelling Above this vapour pressure the proportion of capillary water increases rapidly until at the saturated vapour pressure it fills the whole structure and accounts for about four-fifths of the total water present. From these figures it will be seen that within the range of moisture contents usually met with in practice (say, from 10 to 20 per cent. moisture content or 40 to 80 per cent. relative vapour pressure) the water is mostly held by molecular forces, but that in the initial stages of seasoning green wood the capillary water is of considerable importance, since it is

at these higher moisture contents that the resistance of wood to the hydrostatic tensions set up by capillary water is least.

Further study of the vapour pressure—moisture content isothermals of wood at high vapour pressures has shown[3] that the former conception of the fibre saturation point, as a definite moisture content at which the cell spaces of the anatomical structure are empty and the cell walls are saturated, is a condition which cannot be realised in practice, because at any vapour pressure there must be an equilibrium between the water held in the cell walls and that held in the cell spaces. Any small capillary, whose radius is appreciably larger than the dimensions of the water molecule, will hold water at a vapour pressure lower than saturation owing to the curvature of the free water surface inside it -the smaller the capillary the lower the vapour pressure. For large capillaries this reduction in vapour pressure is inappreciable, but anatomical capillaries may easily be detected microscopically in wood which are small enough to hold water at a vapour pressure measurably below saturation, and which must, therefore, contain water even when the cell walls are not in a state of complete saturation. Thus, if the cell walls are saturated—which can only occur at a saturated vapour pressure—the cell spaces must also contain water, which does not comply with the definition given above for the fibre saturation point. The conception of a fibre saturation point arose from the observation that for all practical purposes the strength of wood was constant above a certain moisture content, whereas below it the removal of water caused an increase in the strength, and, later, other physical properties such as shrinkage and electrical conductivity were found to show a similar dependence on moisture content. This critical moisture content is usually found to lie between 25 and 35 per cent. Recent work has proved, however, that all these properties change as moisture is removed, even at much higher moisture than this, but it is only at moisture contents lower than 25 to 35 per cent. that the change becomes large enough to be observed except by very precise measurement. Thus, while the conception of a fibre saturation point remains extremely useful in problems relating to the practical utilization of wood, it must be discarded in fundamental investigations of moisture relations.

This change in outlook has led to interesting developments in the study of shrinkage.[4] Measurements made by the Seasoning Section on the shrinkage and swelling of thin samples of beech have shown (Fig. 2) that the apparent shrinkage at high moisture contents, which had previously been supposed to be entirely due to the premature surface drying of large samples, persists even when moisture gradients are reduced to a minimum, and that the swelling occurring on re-wetting from dryness does not follow the shrinkage curve at the higher moisture contents. It now appears that only at the lower moisture contents are shrinkage and swelling controlled by the volume of the water removed or added, while at

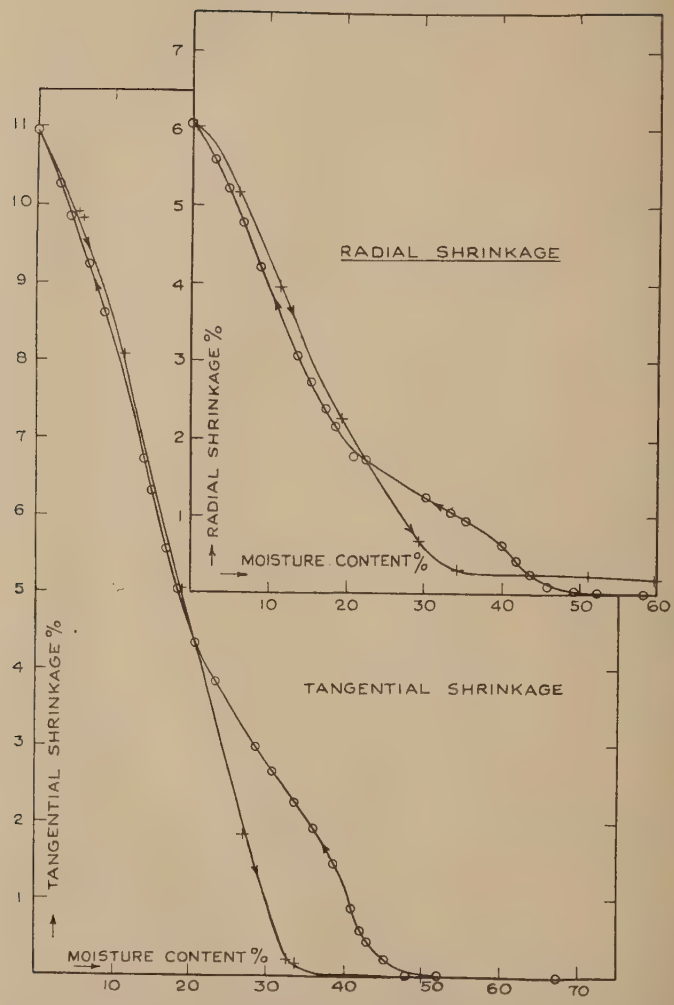

FIG. 2.—*The Shrinkage of Beech at Room Temperature measured from an Initial Moisture Content of 70 per cent.*

the higher it is the hydrostatic tension of the water in the capillaries which principally determines the volume. Since this tension may be calculated thermodynamically it is possible to correlate the degree of shrinkage with the tension producing it, and thus to construct a stress—strain curve for the shrinkage process in the same way as in mechanical testing. Fig. 3 gives this curve for Sitka spruce, and shows that above about 20 per cent. moisture content the tension P is related to the shrinkage S by the equation

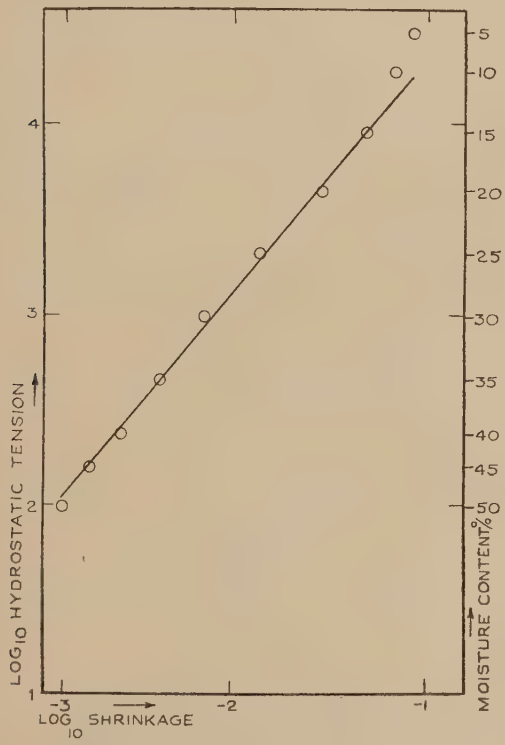

FIG. 3.—*Stress—Strain Relation in Shrinkage of Sitka Spruce.*

$S = a P^k$ where a and k are constants. If the resistance offered by the wood to these hydrostatic tensions is calculated from this expression and is plotted against the moisture content, a curve results which is qualitatively very similar to the curve obtained for the resistance of wood to mechanical forces plotted against moisture content. As can be seen from Fig. 4, where the mechanical property chosen is the crushing strength parallel to the grain, both curves

show a relation between the moisture content and the logarithm of the resistance, which is almost rectilinear for low moisture contents, and which tends towards a more constant value of the resistance as the moisture content is increased. Sufficient information is not at present available regarding the relation between the volumetric and directional compressibilities of wood to make a quantita-

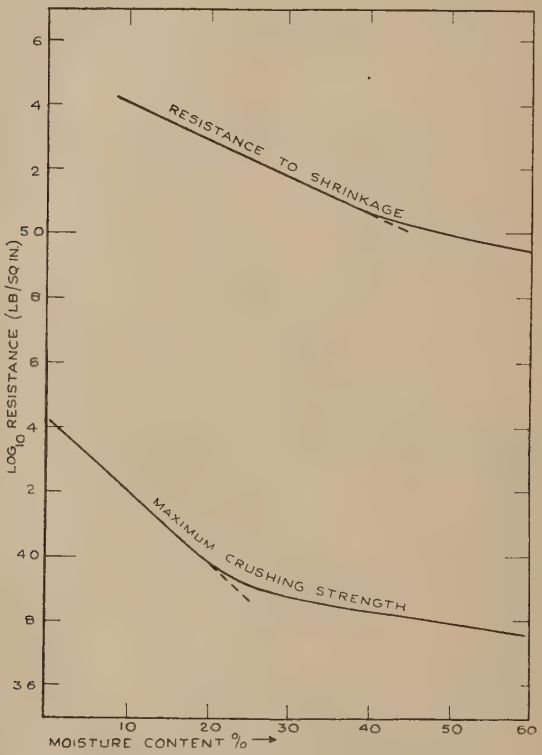

FIG. 4.—*The Resistance to Shrinkage and to Crushing of Sitka Spruce.*

tive comparison between curves of this sort, but it seems probable that at all moisture contents the two should be comparable, while at 12 per cent. moisture content where comparison is possible, it appears that the resistances to shrinkage forces and to external hydrostatic pressure are very similar. Experiments to determine the constants necessary to effect this comparison are now being undertaken by the Section of Timber Mechanics.

The Physics Section is now studying the influence of the rate of drying on the resultant shrinkage.

(1) Barkas, W. W. Wood-Water Relationships (I). *Proc. phys. Soc.*, 1936, **48**, 1–17.

(2) Barkas, W. W. Wood-Water Relationships (III). *Proc. phys. Soc.*, 1937, **49**, 237-242.

(3) Barkas, W. W. Wood-Water Relationships (II). *Proc. phys. Soc.*, 1936, **48**, 576–588.

(4) Barkas, W. W. The Shrinkage and Swelling of Beech and Sitka Spruce Woods at Normal Temperatures. *F.P.R.L. Proj.* **8**, *Prog. Rep.* No. 1, 1936.

The Relations between the Moisture Content of Wood and the Surrounding Hygrometric Conditions

Investigations of the hysteresis effects in the moisture content-humidity relations of timber have been continued. As the result of an earlier experiment it was considered that the lower boundary of the hysteresis zone was the adsorption isothermal drawn from the lowest humidity employed in a particular cycle. Fig. 5 shows the experimental confirmation of this. Between 50 per cent. and 70 per cent. relative humidity, the total hysteresis between the original desorption and the re-wetting from the desiccated state amounts to 2 per cent., but if the timber has been dried to equilibrium in a humidity no lower than 50 per cent., and then allowed to re-absorb to conditions at 70 per cent., the hysteresis effect will be about half this figure. A comparison of Fig. 5 with the curve shown in the 1935 report (Fig. 3 in that report) will show that the moisture content values are in excellent agreement except at the higher humidities on the desorption line. Parallel work in the Section of Timber Physics has shown that the degree of initial saturation influences the equilibrium values in the early stages of the first drying. This was not realised at the time, and beyond ensuring that the moisture content of the samples was well above the anticipated equilibrium at 90 per cent. humidity, no precautions were taken to ensure uniformity of the two sets. The increased knowledge of these moisture relations of timber has indicated the need for revising the equilibrium curves that were prepared some years ago for general use. A standard technique has been arranged, and the work of re-determining the curves has begun. Isothermals for a range of temperatures betweeen 10° and 100° C. are in course of preparation, and further hysteresis tests at normal room temperature are under consideration.

Many attempts have been made to reduce the movement or "working" of timber when exposed to varying atmospheric conditions. Recently the Laboratory has been experimenting in this direction by treating the wood with an aqueous solution of sorbitol.(1) The preliminary experiments were carried out with oak veneers. The veneers were soaked in sorbitol solution for a few hours, and were then exposed to various atmospheres and, when equilibrium was attained, were measured. In this way the movement in changing

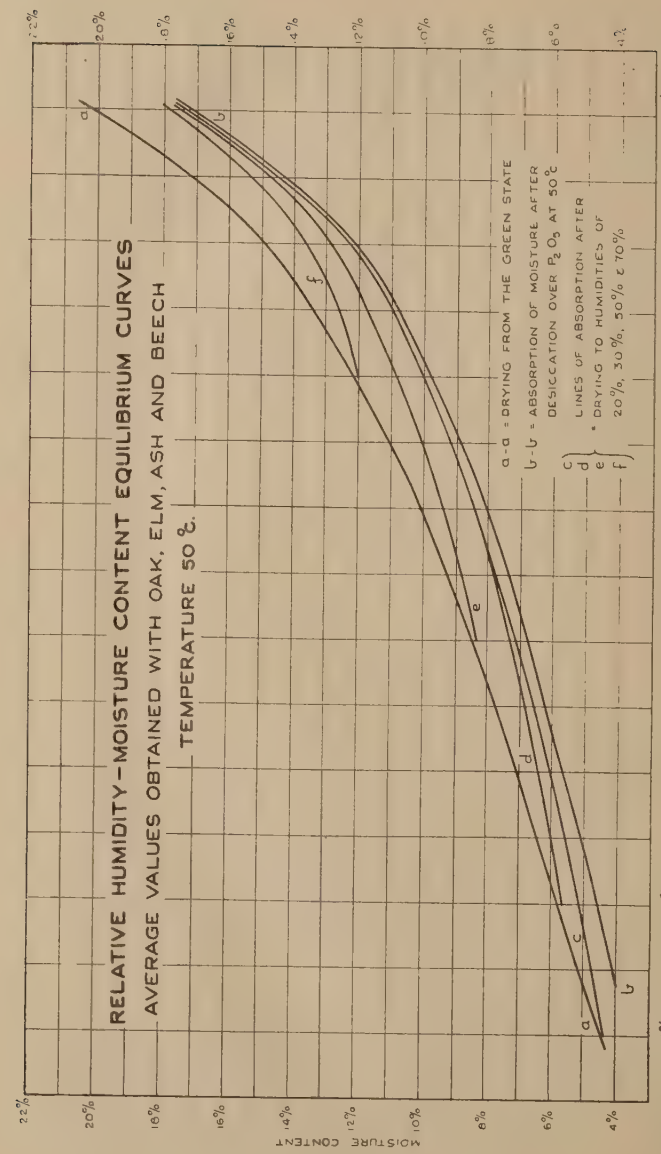
RELATIVE HUMIDITY—MOISTURE CONTENT EQUILIBRIUM CURVES
AVERAGE VALUES OBTAINED WITH OAK, ELM, ASH AND BEECH
TEMPERATURE 50 C.
a-a = DRYING FROM THE GREEN STATE
b-b = ABSORPTION OF MOISTURE AFTER DESICCATION OVER P_2O_5 AT 50°C
LINES OF ABSORPTION AFTER * DRYING TO HUMIDITIES OF 20%, 30%, 50% & 70%
c
d
e
f
MOISTURE CONTENT
RELATIVE HUMIDITY
20%
30%
40%
50%
60%
70%
80%
90%
4%
6%
8%
10%
12%
14%
16%
18%
20%
22%

FIG. 5.

from one atmosphere to another was determined. It was found that the presence of about 25 per cent. by weight of sorbitol in the wood had the effect of approximately halving the movement as compared with untreated matched material. Moreover, though the treated samples became more hygroscopic at high humidities, they did not become objectionably so, *i.e.*, they did not feel damp or clammy.

These experiments are being continued, and the application of the treatment to thicker material is now being studied.

If dried timber absorbs moisture under such constraint that the swelling across the grain is wholly or partly prevented, and is then redried to its original moisture content, its size is reduced. This reduction is termed permanent set, and conditions affecting it are being investigated with a view to their application to flooring, framed panelling and similar built-up wood-work. The term " permanent " as applied to the set is slightly misleading, for if a set sample is released even after a long period of constraint, a slow creep towards normal size will occur, although complete recovery does not take place. Again, if a deformed piece is released from its clamps and re-wetted to a moisture content even slightly above that at which set occurred, the normal expansion appears. It has yet to be found whether set timber will shrink and swell more than normal wood when the set has not been relieved by re-wetting, and this is being investigated.

Of particular practical importance is the rate at which dry timber absorbs moisture when placed in a comparatively damp situation. Data obtained in this connection can be applied to work in new buildings and to dry timber during transport. Tests are being made on the rate of moisture absorption and swelling of a number of commonly used timbers in various sizes, and some results are shown in the following table. These will give the absorption rate when Douglas fir (*Pseudotsuga taxifolia* [*douglasii*]) in equilibrium with a humidity of 60 per cent. is moved to an atmosphere constant at 90 per cent., the temperature in both cases being 25° C.

Rate of Moisture Absorption of Douglas Fir initially at 12 per cent. Moisture Content placed in an Atmosphere at 25°C. and 90 per cent. Humidity

Thickness of material	Time to attain a moisture content of					
	13%	14%	15%	16%	17%	18%
½ inch	6 hours	18 hours	35 hours	60 hours	90 hours	126 hours
15/16 inch	20 hours	54 hours	91 hours	134 hours	190 hours	12½ days
1⅞ inch	23 hours	68 hours	187 hours	377 hours	25 days	59 days

One great advantage of ply- or block-board construction is that the superficial movements are very much reduced as compared with

those of ordinary solid wood under similar conditions. There is, however, little or no diminution of change of thickness, and constancy of this dimension is of paramount importance in the mounting blocks for colour process printing. Some experimental blocks were built with the grain at right angles to the major faces, *i.e.*, with the end-grain in the direction of the thickness. These proved much more stable than the ordinary block as regards constancy of thickness, but the lateral movements were unduly increased. It is probable that these could be reduced to acceptable limits by the use of suitable veneers, but tests on these lines have had to be abandoned for the time being, since the Laboratory possesses no gluing press.

The work of ascertaining the change in moisture content of timber during sea transport has been continued in conjunction with the Forest Economist of Burma, and data have been obtained relating to the behaviour of pieces of teak in various sizes and initial moisture contents.

(1) Bateson, R. G. The Shrinking and Swelling of Wood. Experiments on the Influence of Sorbitol. *Chem. Tr. J.*, 1936, **99**, 493.

The Shrinkage and "Working" of Compressed Wood

Tests have been made to determine the shrinkage and working of compressed beech. Wood compressed radially or tangentially or in both directions is usually referred to as compressed wood, and longitudinally compressed wood as flexible wood. The longitudinal movements of flexible wood for any given moisture content change were found to be greatly in excess of those of untreated material. The radial and tangential movements of compressed wood were also increased as a result of such treatment, but to a very much smaller extent, and in every case the increased movements were found to vary roughly in proportion to the amount of initial "permanent set" induced. Furthermore, an expansive "creep" was a noticeable feature of all the treated specimens subjected to atmospheric (and consequent moisture content) changes, and this "creep" was particularly marked at the higher moisture content values.

Kiln-Seasoning

(*a*) *Experiments in Kiln-seasoning*

The investigation into methods of kiln operation has been continued, 2-in. thick beech planks again being used for the experiments. A close study of treatments in which the kiln is shut down overnight has been made. As compared with a continuously running treatment, this involves keeping the timber in the kiln about 30 per cent. longer, but the actual hours during which the kiln is in operation are reduced by 50 per cent., and steam consumption is lowered by about 25 per cent. The possible economy of this treatment will depend on the relative saving in reduced consumption of steam and power as compared with that involved

in the increased time of drying. No advantage was found in either the drying time or the quality of the dried timber by running the fans continuously during the period when heat was shut off. Similar treatments with unidirectional and periodically reversed air circulation showed slightly to the advantage of the former as regards drying time with a timber stack six feet in width, but the splitting and checking of the timber was lessened when the circulation was reversed. With the object of simplifying the schedule a treatment was applied consisting of only one big drop in the humidity of the circulating air, instead of several small reductions. This was not successful, for it led to a large increase in splitting and checking.

The kiln-seasoning properties of partly seasoned Burma teak flooring have been investigated, and a very wide range of treatments was tried. Under all these the degrade caused by splitting and distortion was negligible, but the difficulty of drying the random sawn material to the necessary degree of uniformity was considerable. The schedule found to be most effective in this respect varied in temperature between 45° C. and 60° C., and included a conditioning period in the twelve-day treatment required. The colour of the kiln-dried timber was extremely variable, and ranged from almost chocolate to pale yellow and green in patches. After about a fortnight's exposure to light and air, however, the timber toned down to the characteristic rich brown of teak. The discoloration during drying did not appear to be increased by the use of very high temperatures unless the humidity were also high.

In continuation of the work on imported timber experiments have been made on partly dried American, Polish and Japanese oaks, and a wide variety of kiln schedules have been tried. The optimum treatment depends on the class of work for which the timber will be used, for apart from questions of permissible splitting and distortion, the matter of colour is often of importance. High temperatures can profitably be used, but they bring about a permanent darkening of the timber, which for some purposes is objectionable. In general terms, these imported oaks present few difficulties in seasoning, save perhaps that care must be taken not to force the drying so that serious inequalities of moisture distribution occur. It is generally advisable to adjust the humidity schedule so that the last few days of the run are of the nature of a conditioning rather than a drying treatment.

Kiln-seasoning experiments were also made on ash, horse chestnut, sweet chestnut, oak and Scots pine. Amongst the Empire timbers, obobonekwi and obobonufwa, Honduras mahogany, mninga, mufumbi, mukusu, mvule and needlewood were tested, in addition to those mentioned specifically above.

(*b*) *The Effects of Varying Air Speeds on the Drying Rate of Timber*

Further tests to determine the effect of air speed through a pile of timber on the drying rate have been carried out on small loads of beech and Scots pine. The width of the pile was 3 ft. 6 in.,

and the layers were separated by 1-in. thick piling sticks. It appeared from these tests that the most favourable air speed depended as much upon the drying schedule as upon the nature of the timber. For the severe drying schedules as used in these tests the drying rates increased until an air speed of 2 ft. per second was reached. A further increase in air speed actually resulted in a slightly decreased drying rate probably brought about as the result of increased turbulence. Although several factors have been shown to influence the value of the optimum air speed for drying a particular load, it would appear advantageous to arrange for an average air speed of some 2 ft. per second to be maintained through a kiln stack, particularly as the usual width of pile is between 5 and 6 ft.

(c) Heat Losses in Kilns

Comparative values for the insulating properties of various kiln parts and materials have been obtained *in situ* by means of a " Blackie " surface heat-flow measuring instrument. The insulating properties of solid brick walls appeared to be particularly susceptible to changes in the air conditions of the kiln so that the heat losses increased rapidly with increase in humidity and consequent increase in the moisture content of the brickwork. It was apparent that such losses could be greatly diminished by facing the inside of such walls with an efficient moisture-proof lining. Tests made at standardised kiln air conditions of 57° C. and 60 per cent. humidity showed that a 9-in. wall of hollow tiles possessed twice the resistance to the passage of heat as that of a similar wall made of 9-in. solid brick, and a 12-in. cavity wall of two rows of single brick with an air gap of about $3\frac{1}{2}$ in. was found to have three times the resistance of a 9-in. thick solid wall. Further, it was shown that a 2-in. thick door made of sheet metal facing with a wooden backing and air space between was twice as resistant to the passage of heat as a door made of solid wood 4 in. thick.

Alterations and Extensions to Seasoning Plant

The three constant temperature and humidity rooms described in the 1935 report have now been completed (Plate 1). The compartment running at 25° C. and 30 per cent. humidity has proved very successful, and the fluctuations in conditions are equivalent to less than $\frac{1}{4}$ per cent. in moisture content of a sensitive wooden sample. Such uniformity has not yet been attained in the 90 per cent. humidity room, where fluctuations amount to about $\pm$ 1 per cent. moisture content. This is receiving attention, and it is hoped to reduce the variations by increasing the number and the fineness of the humidifying sprays.

The reconstruction of the overhead internal fan kiln has been completed, and the most thorough tests of the circulation carried out. These have proved satisfactory, and have led to the simplification of several details of design. A valuable feature of this pattern

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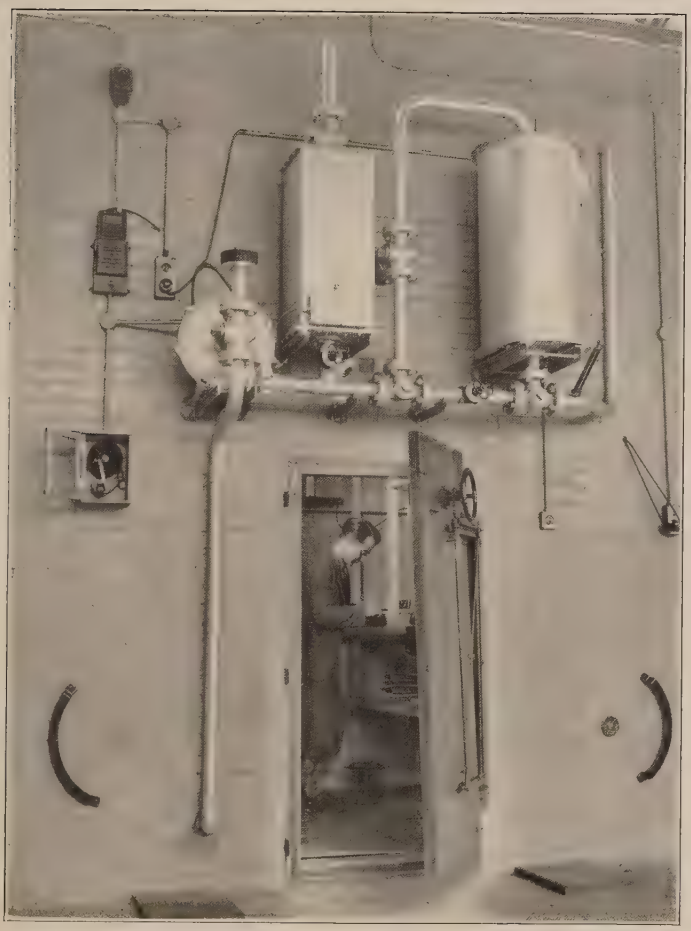
PLATE 1



One of the Constant Humidity Chambers

Exterior view of the chamber maintained at 30 per cent. humidity, showing the automatically controlled air-drying plant.

x 16802

of kiln is that it can be converted from the double- to the single-stack type simply by dropping a canvas curtain down one side of the central air inlet duct. This enables widely varying sizes of load to be dealt with efficiently, for it is poor practice to run a kiln only half loaded with timber.

A second small scale kiln of similar size to that described in the 1934 report has been put into service. It is of the bulkhead type, but the mansard roof has been dispensed with in favour of a flat reinforced concrete construction, and the methods of carrying the fans, heating coils and steam sprays have been improved. The kiln has been in continuous use during the year, and has behaved excellently. This kiln has been fitted with a specially designed wooden door of the self-wedging type mounted on an overhead carrier. This has proved to be reasonably air-tight under severe and widely varying conditions.

In the Laboratory's experience a kiln pile not exceeding 6 ft. in width gives the most satisfactory results as regards uniformity of drying, either with unidirectional or reversed circulation. On the other hand, it is possible that a wider timber stack, although taking longer to dry, might show a saving in the net time per cubic foot of timber. In order to test this, a kiln has been designed in which the width of pile can be varied between 6 ft. and 20 ft. Provision is made for altering the amount and direction of air in circulation, and for such features as regenerative heating between timber stacks. This kiln will be built as soon as funds are available, and will be of wooden construction, a style that has not yet been tested at the Laboratory.

The usual method of drying timber in warm humidified air has its limitations, particularly with such species as dry slowly and irregularly. In such cases the use of low-temperature superheated steam in conjunction with a partial vacuum, or the employment of chemical vapours may be advisable. As a preliminary to such treatments, apparatus is being developed in which they can be tested on a small scale. This kiln consists essentially of a bell-jar housed in an oven, and means of effecting circulation, humidification, the introduction of vapours, etc., are provided.

The covered pit in which paints for protecting metal-work and brickwork of kilns are tested has been in continuous use. A test cycle has been devised in which the widely differing conditions that obtain within a kiln are reproduced in a sequence of twelve-hour periods. The complete cycle lasts a week, and is repeated until failure of the paint occurs. With some types this takes place after only one cycle, whereas others are still reasonably sound after eight or nine cycles. Paints for the different parts of a kiln must be considered separately, for one that gives excellent service on, say, heating pipes in intermittent operation may be useless on the damp and comparatively cool metal near a door, and *vice versa*. A paint that is good on brickwork may soon powder away when

applied to concrete. Those paints which show promise in these accelerated tests are given service trials in the kilns, and while there are strong indications that the two tests are in concord, more complete confirmation is required.

Air-Seasoning

As the basic principles governing the correct procedure in air-seasoning have already been determined, the experiments falling under this category have been limited during the year under review. A number of species from Empire sources submitted for test have been air-seasoned as well as kiln-seasoned, in order to discover any peculiarities arising out of this method of drying, as distinct from so-called artificial drying. The results of these tests are discussed in Appendix II.

In the report for 1934 reference was made to some air-seasoning tests on large furniture squares, bored and unbored. Further results from these tests are now available: $5\frac{1}{4}$-in. oak squares took 9 months to dry to about 25 per cent. moisture content when bored down the middle with a 1-in. hole, and 20 months when left unbored. Thus, nearly a year is saved by boring, and less checking on the ends occurs. Incidentally, when finishing off in the kiln the unbored squares took 38 days to dry to about 17 per cent. moisture content, whereas the bored took less than half this period.

An experiment aiming at determining the best method of handling and piling sycamore for seasoning so that the minimum of darkening and discolouration occurs has just been completed. The preliminary results obtained are being checked and confirmed in a further experiment, but from the data at present available it would appear that the most effective method is that commonly adopted by the trade, viz., piling the timber on end (end-racking) so that a very free air circulation is obtained. This method is, however, wasteful of space, and piling is awkward, necessitating some form of racks or supports to hold the timber. A method which yielded nearly equal results was that of a preliminary rapid surface drying in a kiln prior to piling for air-seasoning in the normal horizontal manner. The most effective kiln treatment tried consisted of piling the planks on edge over the air inlet duct of a natural draught kiln and applying a temperature of 110° F. and a humidity of 60 per cent. for 18 hours. Other methods, including preliminary dipping in a 5 per cent. aqueous solution of borax, the use of special forms of piling sticks and other preliminary kiln treatment gave little or no better results than when the timber was flat piled straight off the saw. In the experiment now in progress some other chemical dips and alternative preliminary kiln treatments are being studied in relation to end-racking.

Stresses set up in Timber during Seasoning

When timber dries the moisture is removed from the surface by evaporation, and it therefore follows that the outer layers will always

be dryer than the centre portions of the timber. Drying, particularly below the so-called " fibre saturation point," is accompanied by shrinkage, and consequently the surface layers of drying timber will tend to shrink more rapidly than the centre. The wetter centre will restrain the surface shrinkage, and a state of stress will be induced.

If the stressing produced is severe strains will result which may have a permanent effect on the timber. A study of the effects of these drying stresses in wood, as determined by the internal strains and " sets " produced thereby, has been made during the year, and a suitable technique evolved. It has been shown that the immediate effect of stressing or casehardening, as it is termed, is to induce a permanent elongation or " set " in the outer layers, but at the same time to induce a yet greater compressive " set " in the centre portions. This compressive " set " of the inner layers tends to augment the subsequent shrinkages of such portions in the same manner as the tensile " set " tends to decrease the subsequent shrinkages of the outer ones. It would appear from the tests so far made that during the final stages of drying the outer layers yield to the forces imposed by the subsequent shrinkage of the core. This yielding of the outer layers is more rapid and complete at higher drying temperatures, and hence the overall shrinkage of wood dried at such temperatures is frequently much in excess of similar material dried at lower temperatures. Finally, it has been shown that yielding of both inner and outer portions of a casehardened board contrives to take place even when the moisture content is kept constant, so that in course of time the internal stresses are gradually reduced.

Wood Bending

Investigations into the bending qualities of sycamore, Canadian maple and birch have been completed during the year, and an investigation into the bending qualities of ash is now in progress. The sycamore tested was found to be a fairly good bending timber when clear, but was very intolerant if the slightest defects such as pin knots were present. The birch also was most intolerant in the presence of such defects, and as very little clear material was available the results obtained were poor. Canadian maple, however, proved to be a good bending timber in general, but definitely required strong and efficient bending apparatus to ensure success. Small scale investigations have been carried out on the bending qualities of the following Empire timbers : waika chewstick (*Symphonia globulifera*), white olivier (*Terminalia* sp.), cypress (*Podocarpus guatemalensis*), and cramantee (*Guarea excelsa*). None of these species was found to be at all suitable for general bending work.

Alteration to Bending Machine

The spring-loaded radial pressure arm on the bending machine has been replaced by the hydraulically operated arm (shown in Plate 2). The ram to which the roller and feed arm are connected is actuated by the main water supply, and is capable of exerting a constant total pressure of any predetermined value up to about 1,000 lb. irrespective of the position of the wood relative to the centre of the table. With this arrangement a large variety of eccentric bends can be made with ease, and in addition it is now possible by placing the form on the end of the ram, to bend according to the lever arm method without recourse to the revolving table.

Apart from the work done on the bending machine a considerable amount of hand bending has been carried out resulting in the design of a very suitable strapping system and independent end-stop attachment for making bends in two planes, and also in improved methods of clamping whereby undesirable distortions may be minimised. As a result of such work it has been found possible to produce complicated bends of the hairpin chairback design similar to the well-known Austrian bentwood chair. A setting chamber has been designed and built, and apparatus installed whereby the forces required to keep bends in shape during drying and " setting " may be measured at any instant.

It has already been shown that bends set much more rapidly at high temperatures than at low temperatures, but it also appears that the degree of " set " is by no means a simple function of the moisture at any instant during the drying. Further tests of this nature are now in progress.

Influence of Kiln-seasoning upon Strength

Mechanical tests have been made in conjunction with a number of kiln-drying experiments to determine to what extent kiln-seasoning affects the mechanical properties of timber. The results confirm previous findings, firstly, that the strength properties of timber kiln-dried under a suitable schedule are the same as those of air-dried timber at the same moisture content, and secondly, that drying at high temperatures involves risk of inducing brittleness in the timber. The latter point will be investigated more fully during the coming year.

Effect of Fungal Infection on the Strength of Wood

An investigation into the comparative effects of attack by brown rot (*Coniophora cerebella* Pers.) and by white rot (*Polystictus versicolor* Linn. Fr.) on the weight, strength and chemical constitution of beech is in progress.

The strength properties chosen for the purposes of this investigation were the compressive strength along the grain and the toughness.

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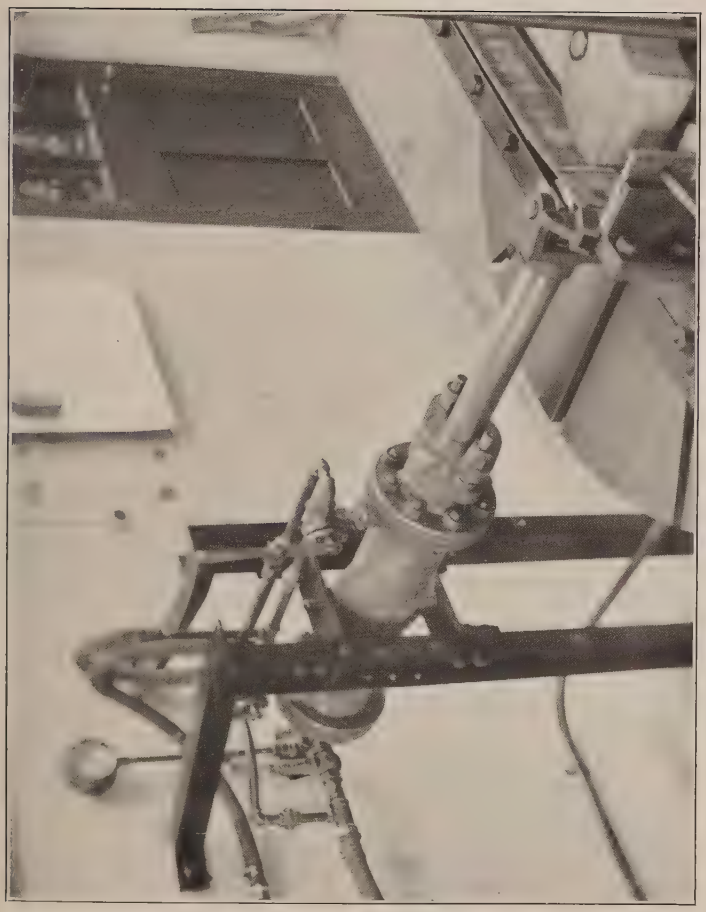
PLATE 2



Hydraulic Radial Pressure Arm on Wood Bending Machine.

In general, fungal infection—where it weakens the timber at all—affects its toughness more rapidly and to a greater extent than any other strength property. This was found to be the case with the above two fungi. Thus after an exposure to the action of the white rot of only two weeks' duration a decrease of nearly 30 per cent. in toughness was recorded, but no significant decrease in compressive strength along the grain occurred until the end of the fourth week of exposure, when a reduction of about 8 per cent. was observed. A progressive loss in weight accompanied this loss in strength. On plotting the loss in weight against loss in strength for timber attacked by the two fungi, it was found that the resultant curves for the brown rot and for the white rot were roughly parallel, and that for any given percentage loss in weight, the loss both in compressive strength and in toughness was greater for material attacked by the brown rot than for that attacked by the white rot. This indicates that where the loss in weight is due to depletion of the carbohydrates only, as is the case where timber is attacked by a brown rot, the resultant loss of strength exceeds that obtained for the same loss in weight produced by depletion of both carbohydrates and lignin, such as occurs where the timber is attacked by a white rot.

Preliminary work has been started on an investigation of the effect of fungal attack on the physical micro-structure of the cell wall with a twofold objective :—

1. To elucidate further the micro-structure of the cell wall.
2. To correlate more closely loss in mechanical strength with changes in this structure resulting from fungal attack, and in particular to attempt to ascertain whether in an early stage of attack by a cellulose-destroying organism, the loss in strength may be due partly to attack on the cementing substances.

It is possible to obtain some indication of the lattice arrangement of the cellulose units by means of X-ray photographs and, with the kind co-operation of Dr. Astbury, of Leeds University, it is planned to take X-ray photographs of thin sections of spruce wood which have been submitted to a tensile test after exposure to fungal attack.

Several series of comprehensive tests have been made to determine what effect, if any, the presence of a blue staining fungus has on the mechanical properties of the sapwood of Scots pine. In the first series in which the effects of a staining fungus on the compressive strength of the timber along the grain and on its toughness were investigated, carefully selected matched groups of test pieces were chosen so as to give a representative sample of the timber from the tree under test. These were infected after steam sterilization with pure cultures of sapstaining organisms and were then tested after various periods of exposure to the action of the fungi.

In the second series similar tests were made after varying intervals of time on matched groups of test pieces which, after having been kept in a moist atmosphere at approximately 25° C., had become naturally stained. In this series the wood had undergone no heat sterilization which, it had been suggested, might make it more susceptible to fungal stain.

In the third series a large number of toughness tests were made on sapwood cut from planks of Scots pine which had developed stain naturally, and an equal number of tests on clean sapwood obtained from boards sawn from the same trees as the stained material, but kept free from stain by dipping in an antiseptic solution.

A fourth series of tests was made on material similar in origin to that of the third series in order to investigate the effect of the staining on bending strength, stiffness and hardness.

The results may briefly be summarised as follows :—No loss in compressive strength along the grain was found either in the artificially infected or in the naturally stained samples. A small but significant loss in toughness occurred in the naturally stained samples which were found on the average to be about 10–12 per cent. less strong than the unstained controls. In the case of the sterilised and artificially infected samples this loss in toughness was in general higher and in one case, after six months' exposure, amounted to as much as 40 per cent. of the strength of the controls. These results are in agreement with those obtained earlier (Report of the Forest Products Research Board for the Year 1934), in which an appreciable decrease in toughness was found to result from the presence of blue stain. No change in bending strength occurred.

A decrease in hardness of the order of 10 per cent. was found in the badly stained material. This again is in agreement with the results of earlier tests on which a report appeared in 1934.

From a practical point of view these results mean that blue stained timber may be used with perfect safety except where very high resistance to shock is required as in aircraft construction. A paper summarising and discussing the results so far obtained in this investigation will shortly be prepared.

The Influence of Black Heart on the Strength of English Ash

Further tests made during the year have confirmed previous findings that " blackheart " ash is not inferior to normal ash in crushing strength, hardness and toughness. A report[1] on the results of the tests has been published.

[1] Armstrong, H. F. The Mechanical Properties of " Blackheart " Ash Wood (*Fraxinus excelsior* L.). *Quart. J. For.*, 1936, **30**, 202–210.

Structural Timber Testing

The report[1] on the tests of British Columbian Douglas fir made during the previous year has now been published. The results show that this timber is both stronger and stiffer than the competitive grade of Baltic redwood.

A report now in the press deals with merchantable Eastern Canadian spruce and "unsorted" Baltic redwood, the strengths of which were found to be of very much the same order, any difference being in favour of the latter.

Considerable time has been devoted to consideration of the problem of deriving safe working stresses for structural timbers, with particular reference to Baltic redwood. The position regarding this timber is rendered more difficult by the lack of any generally accepted system of grading, by the increasing tendency to ship unsorted timber, and by the practice of merchants of abstracting less knotty pieces for use for joinery purposes prior to resale. In view of the general tendency to confine the use of timber for building to the lowest grades, as a first step a mass of test data is being examined in order to determine the possibility of identifying the abnormally weak pieces by their visible defects. In this way it may be possible, by eliminating a small proportion of the material, to raise the safe working stress by a considerable percentage. In view of the variability of wood, any such method must involve some risk of rejecting pieces of satisfactory strength.

For the method to be acceptable the proportion of such pieces must be negligible. This point is now under investigation.

[1] Chaplin, C. J., and Nevard, E. H. Strength Tests of Structural Timbers. Part 2. General Procedure of selecting and testing Joists, with Data on British Columbian Douglas Fir (*Pseudotsuga Douglasii* Carr.). *For. Prod. Res. Rec.*, 1936, No. **8**.

Strength Properties of Home-grown Timbers

To supplement existing data further consignments of sycamore, European larch and wych elm have been tested.

Miscellaneous Strength Investigations

Enquiries having been received from time to time for information concerning the relative strength properties of the heartwood and sapwood of home-grown oak, some tests were made on specimens cut in a systematic manner from a log of this species. The specimens were tested in the green condition. It was found that there was a decrease in density and strength from the pith outwards. In the three zones, sapwood, heartwood adjacent to sapwood and heartwood near pith, the approximate ratios of density and bending strength were respectively 80 : 90 : 100 and 65 : 80 : 100. This result of tests made on a single log tends to indicate that the sapwood is lower in strength than the heartwood ; this is not due to any basic difference between sap and heart, but merely reflects the progressive

change which takes place from the pith outwards in the wood throughout this tree. These tests were made on green timber, but it is expected that seasoned timber would give similar results.

A parallel investigation on Scots pine is in progress.

Tests have been made to determine the relationship between the values obtained for the resistance of a timber to suddenly applied loads as measured by :—

(1) the height of drop of the standard hammer as employed in the Hatt-Turner test,
(2) the energy absorbed in breaking an unnotched specimen in the pendulum impact type of testing machine,
(3) the energy absorbed in breaking a short notched specimen as in the Izod test.

Tests on Timber from the Piles of Waterloo Bridge

Some small portions of piles from Waterloo Bridge were made available for strength tests. As the material was very limited in amount only a few tests were possible It was found that whereas the timber (elm, probably *Ulmus procera*) was as hard as the average of common elm as tested in this Laboratory, it was appreciably lighter in weight and lower in crushing strength along the grain. In this latter property the timber was, in fact, for the most part below the range of strength of any elm tested previously.

Box Testing

In the Report of the Forest Products Research Board for 1935 mention was made of projected alterations to the tumbling drum. The necessity for these alterations arose from the fact that at the time of its development at the Forest Products Laboratory at Madison, Wisconsin, U.S.A., the machine was required solely as a convenient means of subjecting boxes to a treatment which simulated the rough handling encountered in transit, thus enabling the development of failure to be studied and improvements in design to be effected. For this purpose it was unnecessary that the series of falls should be very strictly reproducible. At this Laboratory, however, the bulk of the work consists of comparative tests frequently with reference to damage to the contents, the chief essential of which is that the test shall be strictly reproducible in order that the boxes under comparison shall receive the same treatment. This requirement is now fulfilled, the drum having been fitted with adjustable guides and " hazards " which are set to positions calculated from the dimensions of the box under test. In its amended form the drum test represents a very considerable advance on previous practice. A description of these alterations has been published.

Considerable progress in the tests for the Ministry of Agriculture and Fisheries in connection with the preparation of a specification for fibreboard containers for the conveyance of eggs under the National Mark Scheme has been made. As the initial tests indicated

that the protection afforded to the eggs depended much more on the internal fittings than on the outer container, subsequent work has been concerned chiefly with the former. After considerable experimental work a combination of container and fittings has been evolved which laboratory tests indicate provides much greater protection than the types at present in use without increasing the costs of manufacture or packing. Rail and road transit tests are now being carried out to determine the efficacy of this combination under service conditions.

At the request of the Union of South Africa an inspection was made at Covent Garden Market of a trial shipment of approximately a thousand orange cases. The shipment had been arranged as part of an experiment with a view to the development of a suitable case constructed of native timber, such cases forming part of the shipment, the rest being of imported shooks assembled in the Union.

On behalf of the Dominion of New Zealand a series of laboratory tests was carried out on boxes for the export of butter in 50-lb. blocks. This work formed part of an investigation of the New Zealand Department of Agriculture with the object of providing a substitute for the standard white pine box.

A considerable programme of tests of boxes and of the material used in their construction has been carried out for makers and users of boxes in this country. The scope of this work is indicated by the following list of products conveyed in the boxes :—Eggs, butter, canned fruit, canned vegetables, wireless receiving instruments, confectionery, syrup, soap products of various kinds, canned fat, bottles of whisky.

Woodworking Research

The working qualities of twenty different species of overseas timbers have been determined during the year. In each case the behaviour of the timber under normal working conditions has been studied for all the common operations, and comparison made with species already well-known in the wood-using industries.

By this means it has been possible to estimate how each timber would react to commercial handling and whether modifications to the tools, speeds or other factors would be needed to produce satisfactory results. It has been necessary with several of the timbers tested to diverge widely from standard practice before, for instance, a reasonably good finish or a normal rate and ease of production could be ensured. The experimental work carried out in such cases often produces results of wider application than merely to show the conditions required for the particular timber. It may indicate some method of improving the working of other refractory timbers, or show that, in a certain operation, a modification to the standard shape of tool could be adopted universally with advantage. For example, it has been found through experiment that a wide

tooth spacing is of great assistance in minimising the blunting of the teeth when sawing timbers which have a high content of silica.

In addition to the experiments sometimes necessary as a final stage of routine testing, investigations are being carried out to determine the inter-relationship of cutting speed, angle at which the cutting face of the tool meets the wood, rate of feed, depth of cut and other factors which influence the finish, the resistance to cutting and feeding, and the wear on the cutting edges. Special machinery is needed for this class of investigation, and it has been necessary to design and construct a variable speed feed-gear combined with measuring apparatus for use with a planing machine. The latter is already provided with means for altering the cutting angle and the peripheral speed of the knives and for measuring the power absorbed in planing the wood. This apparatus, now nearing completion, will provide an accurate record of the varying resistance to feeding offered by a timber under different conditions of cutting. It will be possible therewith to determine, for rotary planing operations, the inter-relationships of the factors mentioned above, and hence the optimum working conditions for individual species of timber. Its use will also enable comparison to be made between different species, and variation within a species to be measured.

A considerable amount of work has been done on somewhat similar lines in connection with measuring the resistance offered by wood to rectilinear cutting. The primary object of the investigation was to ascertain the effect of various softening treatments on the " cutability " of wood. In these studies only small samples had to be tested, and it was found convenient to employ a microtome for cutting the wood and to adapt apparatus designed for measuring the relative smoothness of machined surfaces to record the resistance offered to the microtome knife. With this arrangement (Plate 3), fine adjustment of knife position relative to the wood, of depth of cut and of speed of cutting was possible, and the response of the measuring apparatus to very small changes in resistance to cutting was excellent. Preliminary work was concerned with finding the most suitable conditions of cutting to provide maximum sensitivity and accuracy. Tests were then made on series of pairs of untreated and treated matched samples, the results of which showed the efficacy of various treatments in improving the cutability of the wood. Further studies will be undertaken with the object of relating cutability to the anatomical structure of wood, comparing different species and adding to existing knowledge of the reaction of wood to cutting tools.

Measurement of the abrasive effect of a timber on saw teeth and knife edges is required, and apparatus incorporating a sensitive dial gauge has been constructed for this purpose. The data obtainable allow comparison to be made of timbers in this relation, and are of assistance when estimating the proportionate cost of working a timber likely to be a substitute for another in general use. The

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PLATE 3

Apparatus for measuring Resistance to Cutting.

relative merits of different types of steel, the effect of hardening treatments and the suitability of tool shape, setting and speed can be assessed by this means.

Practical studies have also included the design, construction and testing of a power frame saw for a special use, and of bow-saws for felling and cross-cutting young trees in thinning operations; the reduction of noise from high-speed circular saws; the testing of a commercial design of cutterblock having adjustable cutting angle; the sawing of plywood (normal, metal-faced and uralite-faced), and the effect of different seasoning treatments on teak, various classes of oak, and other timber. A number of firms engaged in the wood-using industry have been visited, and their machining problems investigated; the possible utilisation of sawdust and other wood waste has also been studied.

Special courses of instruction in woodworking practice, saw and cutter maintenance and related subjects have been given in a number of cases. Testing technique and the application of the results of such work have been demonstrated to and discussed with members of the timber trade, technical students and other visitors to the Laboratory. There has been a marked increase in the interest shown in this research and the demand for advice on specific problems has grown considerably. The information obtained from the investigations has also been made available through official publications, articles in the technical press and display at various exhibitions. Notes on the working qualities of twenty home-grown timbers have been prepared for inclusion in the revised edition of the Laboratory's publication, " The Uses of Home-grown Timbers."

Tests on Wood Preservatives

The degree of permanence is an important factor in wood preservatives and laboratory tests on these materials frequently include a leaching test to provide an indication of their relative permanence. Apart from the diversity of opinion that exists regarding the value of such tests and the interpretation of the results there is also frequent criticism of the method employed for the leaching. It is not possible to establish an experimental procedure that will correspond to the conditions which arise in actual practice, so that the aim of a satisfactory test is to standardise the conditions in order that tests can be carried out by different operators to give similar results and at the same time reproduce practical conditions as far as possible. Thus workers who have used hot water for the leaching have been strongly and adversely criticised and the majority prefer to use cold water.

The usual method of carrying out the extraction is to place the treated wood sample in a bottle or other container to which a fixed volume of cold water is added. The bottle and contents are then shaken, usually in a machine, for a definite and large number of times, and the washing water is analysed chemically to provide the measure

of the leaching that has taken place. The main objections to this method are two-fold. In the first place there is a tendency, especially in the case of preservatives of relatively low solubility, for a saturated or nearly saturated solution of the salt to be formed, in which case the results show the preservative in a too favourable light. Secondly, if one attempts to overcome this objection by refilling the bottle with fresh water the volume of wash water to be eventually analysed becomes almost excessive or, at any rate, inconveniently large.

In the course of work on certain water soluble preservatives it was found necessary to carry out leaching tests on wood samples treated with these preservatives, and an apparatus was used which largely overcame the above objections. The apparatus, which was constructed in heat-resisting glass, consisted of a modified form of a Soxhlets Extractor. The vapour, in this case steam, was led to the top of the condenser, which was of the spiral type and of adequate dimensions, so that the water falling on to the wood contained in the extractor was well cooled. Use of this apparatus admits of a standardised washing of the samples, using a relatively small amount of washing water, while the actual wood is being constantly washed with fresh water.

Leaching tests on various water soluble salts using this apparatus have been started.

The Structure of Wood and its Preservative Treatment

Work on the relation between the anatomical structure of wood and its preservative treatment has been confined during the past year to the investigation of various anomalies encountered during routine impregnation tests. Irregular penetration of creosote in New Zealand beech (*Nothofagus menziesii*) was found to be due to the localised development of tyloses and gum plugging the pores. A similar condition is often found in the beeches of the northern hemisphere, and is believed to be due to certain climatic conditions having an irritating effect on the living cells of the sapwood. Another matter of interest was the extremely wide range in permeability of jarrah (*Eucalyptus marginata*). This variation was found to be associated primarily with differences in the nature rather than in the amount of gum present, and less intimately with differences in the type of tylosis development.

Preservative Treatment of Railway Sleepers

The computations involved in the treatment of the 4,400 sleepers for service tests have been completed and a progress report has been prepared giving details of treatment and the results obtained. Baltic redwood sleepers are usually creosoted by a full cell process, which is applied until about 9 lb. per cubic foot has been injected, the greater part of which is absorbed by the permeable sapwood.

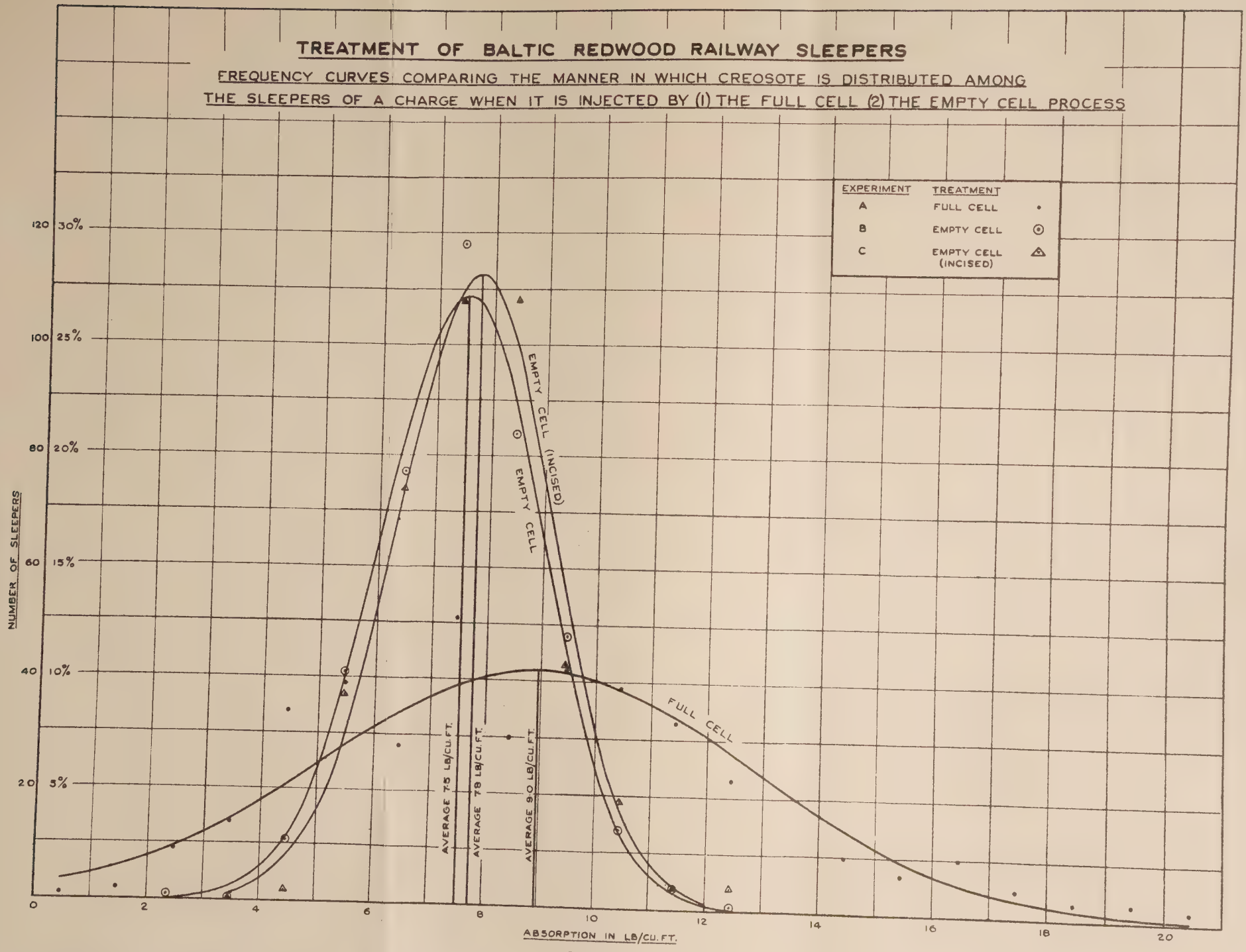

FIG 6.

(3220)W[E]20378, 875.|[1]37G[P]921C&RL[TD]

As the sapwood will absorb creosote rapidly even under low pressures the required amount of creosote is injected before the more resistant heartwood faces of the sleepers become deeply penetrated. If the treatment were maintained until adequate penetration of these faces were achieved (about 18–20 lb./c. ft.) the absorption of creosote would be much too high because of the complete saturation of the sapwood. A much better distribution of the creosote results if it is injected by the empty cell process, for it is possible by using this process to impregnate the sapwood completely without saturating it, and at the same time to maintain the treatment until the heartwood faces of the sleepers are adequately penetrated. A still deeper and more uniform penetration into the heartwood is obtained if these faces are incised. This better distribution of the creosote was confirmed by examination of a number of the sleepers treated. It was also found that the creosote injected by an empty cell process was much more uniformly distributed throughout the component sleepers of a charge. For example, the individual sleepers treated by the full cell process absorbed amounts varying from 1 to 20 lb. per cubic foot of creosote, whereas the variation in the case of the empty cell treatment was from 2 to 12 lb. per cubic foot. This effect is shown graphically in Fig. 6, which gives the frequency curves for absorption by individual sleepers treated by the full cell and empty cell processes.

The more uniform absorptions obtained with the empty cell treatment are of importance as tending to eliminate the small proportion of poorly impregnated sleepers which, by necessitating early renewal, increase the cost of track maintenance.

Effect of Moisture Content on Creosote Treatment of Canadian Douglas Fir Sleepers

Confirmatory tests carried out on the impregnation of Douglas fir sleepers showed that sleepers treated on arrival, at a moisture content of 27 per cent., absorbed 33 per cent. more creosote than similar matched sleepers which were allowed to season over a period of 9 months to a moisture content of 20 per cent. Examination of results revealed no relationship between the average moisture content of each sleeper and its absorption of creosote in lb. per cubic foot. If, however, the absorption was expressed as percentage of air space impregnated, and plotted against the moisture content of the outer 1-in. layer of the sleeper, there was a definite indication that the absorption of creosote was affected by the moisture content of the wood. The data provided by the treatment of these sleepers was not sufficient to define this relationship, but it indicated that absorption tended to decrease rapidly as the moisture content decreased to about 24 per cent., beyond which further drying reduced the absorption by a relatively smaller amount. It appears, therefore, that the moisture content of the surface of the timber becomes of much greater importance than the average value for the whole sleeper, and that when the surface has dried much below 25 per cent.

moisture content the penetration of the creosote may be seriously retarded. This effect may be the explanation of the difficulty often encountered in the creosoting of Douglas fir in hot climates and sometimes attributed to " casehardening ".

These results indicate that in the case of Douglas fir sleepers long periods of seasoning before treatment are not necessary, and are even undesirable if the maximum penetration of creosote is to be obtained.

Fence Posts

Periodic examination of the experimentally treated fence posts erected in 1932 has been continued. The results so far indicate quite definitely that charring has very little preservative value (Plate 4). If the charred posts are dipped in creosote, however, the preservative effect is considerably increased, but to what extent cannot yet be determined. Tarring the posts is another popular treatment which from the results of these tests would appear to have only slight preservative value for fence posts.

Creosote Treatment of Spruce Fence Posts

There is considerable diversity of opinion regarding the ease with which Norway Spruce can be impregnated with creosote. The general opinion is that this timber is very resistant to treatment, but a number of cases have been reported where excellent impregnation has been obtained by the hot and cold open tank process. Experiments were carried out with the object of finding the cause of this variation in resistance to impregnation and also to determine the most suitable method of treating the timber. The results of tests on material from four different sites showed that best results were obtained by pressure impregnation of seasoned material. Fairly good but variable results were obtained by the hot and cold open tank process, and it was found that the higher the temperature of the hot bath the better the impregnation obtained. In the experiments a maximum temperature of 230° F. was employed satisfactorily. Increased absorption and penetration was also obtained by repeating the heating and cooling cycle. In some of the material the presence of a brown-stain caused by the fungus *Stereum sanguinolentum* was responsible for high local absorption of creosote.

Laboratory Tests on the Fire Resistance of Timbers

Tests have now been developed for the relative estimation of the fire resistance of timber, both in its natural state and treated with fire-proofing chemicals. Three different tests have been adopted for measuring the individual factors of inflammability, resistance to flame penetration and rate of burning. Tests are proceeding on untreated timbers and on certain fire-proofing treatments.

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PLATE 4

Charred Oak Fence Post after Three Years in the Ground, showing Fruiting Bodies of Polystictus versicolor.

Factors Affecting Lyctus *Attack*

(*a*) The Food of *Lyctus* Beetles

In continuation of the work mentioned in the last report, a further series of experiments has been started in order to discover by what criteria female *Lyctus* Powder-post beetles determine the suitability of wood for oviposition. It has been shown [1] that the amount of starch in the wood is an important factor, but there may be others. Examination of the experimental samples, which have been treated in various ways calculated to increase or decrease their attractiveness, has been completed, but the results have not yet been analysed.

[1] Parkin, E. A. A Study of the Food Relations of the *Lyctus* Powder-post Beetles*. *Ann. appl. Biol.*, 1936, **23**, 369-400.

(*b*) Emergence and Flight of *Lyctus* Beetles

The light trap experiment was repeated in 1936, and the results were again disappointing, owing to the poor emergence of beetles from the insectary material.

The Control of Lyctus *Beetles*

(*a*) Methods of Starch Depletion

The experiment, which was started in 1935, to ascertain the effect upon the starch content of oak sapwood of girdling trees some time before felling, has been continued. Discs and borings from two trees girdled in July, 1935, and felled in the following December, have been examined, but definite conclusions as to the effect of the treatment cannot be drawn until samples from the remaining trees, girdled at the same time but not felled until December, 1936, have been investigated. Borings have been taken and examined, and the arrival at the Laboratory of the selected discs is now awaited.

Dr. F. Y. Henderson, working at the Imperial College of Science and Technology on the relation between the rates of starch depletion and respiration of ash, has shown[1] that it is possible to accelerate the removal of starch from green timber by moist heat treatment, and has suggested that, by keeping the wood at a temperature and humidity near the optimum for the living cell, starch-free timber could be obtained within a period which would allow the use of the method in commercial practice.

In exploring this possibility the Laboratory, which is co-operating with Dr. Henderson by exposing his samples to *Lyctus* attack, has carried out an experiment on a semi-commercial scale, in which a small load of green 1-in. oak and ash boards containing an abundance of starch was kept in a kiln at 39° C. and 95 per cent. relative humidity for one month, during which the progress of starch depletion was carefully watched. Examination of the boards

* Thesis approved for the Degree of Doctor of Philosophy in the University of London.

then showed that the reduction in starch content was very uneven, one part of a board being starch-free, whilst a neighbouring portion had a starch content well above the *Lyctus* immunity level.

It has become apparent during the year that little further headway can be made on this question of starch depletion until more is known of the natural occurrence of starch in wood, its form, distribution, reaction to different strengths of test solutions and of the effect upon it of different seasoning processes and extreme heat. The Entomology Section is therefore co-operating with the Wood Structure Section in planning and carrying out a series of small scale experiments which should throw light on these important points.

[1] Henderson, F. Y. Timber and Attack by *Lyctus* Beetle. *Ann. Bot., Lond.*, 1935, **49**, 854-856.

(*b*) Kiln Sterilisation Treatment

The determination of the periods of exposure required to kill larvæ in timber at kiln temperatures of 105°–125° F. and relative humidities of 60 or 80 per cent. has been completed, and an account of the investigation written up in a form suitable for publication.

(*c*) Laboratory Tests of Wood Preservatives for the Prevention of *Lyctus* Attack

Further tests have been undertaken with aqueous solutions of water soluble salts applied to oak sapwood by an immersion treatment. Five per cent. solutions of zinc chloride, sodium silicofluoride, borax and potassium chromate, and a 3 per cent. solution of sodium fluoride have been used. After an immersion period of 5 minutes it was found that a 5 per cent. solution had deposited 0·0004–0·0008 gm. of salt per sq. cm. of wood surface. The samples were exposed to *Lyctus* attack approximately two months after treatment, but none of the salts prevented infestation at the concentrations mentioned. It is possible that solutions of greater strength would be more effective, but it is evident that, owing to the very superficial penetration obtained, aqueous solutions, unless applied by pressure impregnation, are at a disadvantage for use against an insect which lays its eggs beneath the surface of the wood.

In addition to the tests with water soluble salts, similar experiments have been undertaken with a 20 per cent. solution of a chlorinated naphthalene wax in benzene. This preservative has proved effective in preventing *Lyctus* attack, and further tests are now in progress in which the samples of oak sapwood have been exposed to *Lyctus* one year after treatment.

Instances of Damage by Wood-boring Insects

Two cases of *Lyctus* infestation of special interest have come to notice, one concerning damage to walnut panelling in a liner, and the other connected with extensive damage in several large consignments of Japanese-oak-faced plywood. Three instances of the

occurrence of the Bostrychid Powder-post beetle (*Schistocerus hamatus*) in the sapwood of American oak were also of interest. This insect is a native of the U.S.A., where it is recorded as attacking the twigs of various trees, but it is apparently not known in that country as a borer in timber.

The Death-watch Beetle (Xestobium rufovillosum)

Considerable time has been occupied during the past year in preparing for publication the results of the Laboratory's investigations on the biology of the Death-watch beetle. Further experimental work has, however, been carried out, particularly with reference to the relationship between moisture content of timber and rate of development of the larvæ. Although the experiments concerned are still in progress, the results so far obtained confirm those of preliminary studies, and show that decayed timber of moisture content 16–20 per cent. is more suitable than that of 10–16 per cent., whereas similar wood at 8 per cent. moisture content and less is unsuitable for larval development.

The investigations referred to in the last report [1] on the effect of fungal decay have been continued. As yet fungi of the white rot type only, *Phellinus cryptarum* in oak sapwood and *Polystictus versicolor* in willow, have been used. Although no detailed examination of the infested samples is intended until the insect has completed its development and emergence has taken place, it is already apparent that larval development is much more rapid in severely decayed wood.

Attention has been directed in previous annual reports to the importance of moisture content, decay and temperature in determining the rate of development and, consequently, the rate of increase of damage by the Death-watch beetle. In this connection it is of interest to note that during the past year the first results have been obtained in the course of the Laboratory's investigations of the duration of the life-cycle under outdoor conditions. These show that in oak sapwood decayed to a moderate extent by *Phellinus cryptarum* the insect required five years to complete its development. In contrast to this the length of the life-cycle may be as short as 1–2 years in severely decayed wood at a temperature of 25° C., and at a moisture content of approximately 20 per cent.

As in past years, the Laboratory has been called upon to inspect buildings in order to advise on treatment of structural timbers damaged by *Xestobium*. In the course of this work, and during a number of special visits paid to buildings in which repairs and treatments were in progress, the variation, in different parts of the country, in methods of treatment of infested timbers and the extent of replacement considered necessary are worthy of note. There is need for a wider knowledge of the conditions favourable for the development of the Death-watch beetle and of the limited value

of surface applications of insecticides, which cannot be expected to destroy larvæ working at appreciable depths within timbers of large dimensions. The desire for this knowledge is indicated by the demand for the Laboratory's leaflet on *Xestobium* and its control, a third revised edition of which was published during the year, making available a summary of the most recent information on the insect.

As a means of spreading such knowledge, and to stimulate the interest of all concerned in the care and maintenance of old buildings, the Laboratory has prepared a film which shows the different stages in the life-cycle of the Death-watch beetle, the damage caused and the positions in which it most frequently occurs, and also the methods used for rearing it and studying its habits and rate of development.

(1) *Report of the Forest Products Research Board for the year* 1935. H.M. Stationery Office, London (1936). Price 2s. net.

Pinhole Borers

An interesting case of damage to English ash by the pinhole borer, *Platypus cylindrus*, was noted.(1) Examination of the timber showed that infestation had occurred in the standing tree at a time when the growth increment suddenly became noticeably less than in the years immediately preceding infestation. The attack did not, however, continue, and the insect tunnels became entirely occluded by the formation of new wood. This record is of special interest in relation to the frequent occurrence of a similar type of defect in standing trees in the tropics.

The paper read at the Fourth Imperial Entomological Conference, 1935, on the need for investigation of the pinhole borer problem has now been published.(2)

(1) FISHER, R. C. Note on Incidence of Attack by the Pinhole Borer, *Platypus cylindrus*, in English Ash. *Bull. ent. Res.*, 1937, **28**, 1–3.

(2) FISHER, R. C. The Need for Forest Entomologists, with Special Reference to the Pinhole Borer Problem. *Emp. For. J.*, 1936, **15**, 201–209.

Sirex *Wood-wasps and Fungus Association*

A silver fir tree showing signs of a heavy attack by wood-wasps, which subsequently proved to be *Sirex cyaneus*, was obtained in the early summer of 1936. Examination of numerous sections and dissections has shown that no important difference exists between the fungal association of this species and *S. gigas*, which was previously studied, but no further light has yet been thrown upon the method whereby the fungus is transferred from one stage of the insect to the next.

The House Longhorn Beetle

Two further instances of damage by the House Longhorn (*Hylotrupes bajulus*) have been investigated during the year.

Physiology of Digestion of Wood-boring Larvæ

In view of the confirmatory evidence, obtained by a study of the enzymes in the larval alimentary canal, of the importance of starch as a food of *Lyctus* larvæ, the scope of this part of the investigation has been extended and the digestive enzymes of a number of other wood-boring larvæ belonging to the families *Scolytidæ*, *Cerambycidæ* and *Anobiidæ* have been determined.

Fumigation

An account of the work carried out during 1935 to determine the concentration of hydrocyanic acid gas and the periods of exposure necessary to kill *Lyctus* and *Anobium* larvæ removed from the wood, and *Lyctus* beetles, has been completed and accepted for publication.[1]

The investigation, in co-operation with the National Physical Laboratory, into the rate of penetration of gases into wood has been continued. To gain some insight into the problem without experimenting with highly toxic gases themselves, experiments have been made with hydrogen, sulphur dioxide and carbon dioxide, and these have shown that the rate of penetration is sufficiently rapid to justify the hope that hydrocyanic acid gas might be used successfully on small articles such as furniture, and possibly also for buildings containing the more easily penetrated species of wood. It is known, however, that hydrocyanic acid gas is readily absorbed by the wood and retained with some tenacity, so that direct experiments with this gas will be necessary before it can be ascertained how far it may be used without fear of its subsequent release in dangerous quantities.

It must be borne in mind, however, that in practice the presence of exit-holes in the surface of infected timber may materially aid penetration, and this is supported by the results of two experiments carried out in a chamber used commercially for the hydrogen cyanide fumigation of furs, carpets, furniture, etc., infested by clothes moths, in order to determine whether the treatment would be suitable for application to furniture attacked by wood-borers. In the first test not all the larvæ were killed in the experimental samples containing *Lyctus* larvæ, and recommendations were made which, in a subsequent experiment, gave satisfactory results.

[1] Parkin, E. A. and Busvine, J. R. The Toxicity of Hydrogen Cyanide to Certain Wood-boring Insects. *Ann. appl. Biol.*, 1937, **24**, 131-143.

Destruction of Wood-boring Insects by Means of X-ray Treatment

At the request of Dr. P. D. Ritchie, head of the Scientific Department of the Courtauld Institute of Art, numbers of larvæ of *Lyctus* Powder-post beetles and samples of timber containing larvæ of various wood-boring insects were supplied for exposure to X-ray treatments. Subsequently the insects and samples were examined at the Laboratory to determine the effects. Although none of the

insects was killed, the experiments confirmed previous indications that X-ray photography might be used as a means of detecting the presence of insects in such articles as valuable panelling, picture frames, etc., but that its use would be restricted by the thickness of the infested wood.

Detection of Wood-boring Insects by Audio-frequency Amplifier

The improved type of amplifier and associated apparatus referred to in the last annual report has been completed by the National Physical Laboratory, which has published[1] a description of it. Its use is restricted to the detection of the presence of wood-boring insects in specimens which can be placed in a sound-proof box, but has already proved of value at the Forest Products Research Laboratory, for selecting infested samples of wood for insecticide tests when it was essential to ascertain whether living insects were present without detailed examination by cutting up the specimens.

[1] COLEBROOK, F. M. The Aural Detection of the Larvæ of Insects in Timber. *J. sci. Instrum.*, 1937, **14**, 119–121.

Decay in Oak Wood

A monograph describing the principal types of rot found in English oak, and illustrating the fungi responsible, has been published.[1] A paper, describing in detail the fungus responsible for brown oak (*Fistulina hepatica*), is in the press.[2] Further oak trees in Bagley Wood, Oxford, have been inoculated with plugs of wood infected with this fungus, and two branches infected last year have been cut off and examined, when it was found that the discolouration had spread longitudinally about 6 in. in the heartwood in each direction from the point of inoculation. Cultures were made from the discoloured area and the same fungus isolated in culture.

[1] CARTWRIGHT, K. ST. G. and FINDLAY, W. P. K. *The Principal Rots of English Oak*. H.M. Stationery Office, London (1936). Price 2s. net.

[2] CARTWRIGHT, K. ST. G. A Re-investigation of the Cause of ' Brown ' Oak. (In the press.)

Decay in Softwoods

Considerable progress has been made in collecting material for a publication on the principal decays of softwoods on similar lines to the one already published on the rots of oak. As a great deal more work has already been done on the principal fungi responsible than was the case with the oak fungi, much abstracting from the literature on the subject is necessary in addition to the new investigations required, but it is hoped to complete the volume in the coming year.

As was noted in the last report, a number of spruce poles received at the Laboratory were found to be affected with a brown stain, which favourably affected the absorption of creosote during impregnation. A short paper has been prepared for publication describing the results obtained in treating these poles and reporting that the

organism responsible is *Stereum sanguinolentum*. Laboratory tests have now shown that this fungus is capable of producing very quickly in quite an early stage of decay a similar dark brown stain when cultivated on spruce sawdust. This discoloration is probably due more to the secretion by the fungus of a dark-coloured liquid than to decomposition of the lignocellulose complex. In view of the comparatively frequent occurrence of this stain it is planned to investigate the disease further.

It is of interest to note that *S. sanguinolentum* is the fungus which is associated with *Sirex gigas*, and that it is sometimes introduced into trees by that insect.

Laboratory Tests on Wood Preservatives

The toxicity of a further number of proprietary and other wood preservatives has been determined by means of wood block tests.

The panel formed by the Committee of the British Standards Institution which is considering the desirability of setting up standard tests for antiseptics decided at its first meeting that those members who were willing to co-operate and had laboratory facilities should undertake to carry out toxicity tests along the lines suggested by the Laboratory's representatives, on standard samples of creosote and of sodium fluoride, and that when the results of these comparative tests were available they should be discussed at further meetings with a view to establishing a provisional British Standard Specification for laboratory tests on the toxicity of wood preservatives. The Laboratory is co-operating in these tests, and has provided samples of antiseptics and wood blocks for the members of the panel who are undertaking the comparative tests.

Laboratory Tests of Natural Durability

Laboratory tests on the durability of a further number of colonial timbers have been completed. Among timbers recently tested that have shown a high resistance to fungal decay are :—

Rhodesian teak—*Baikiæa plurijuga*.
Borneo camphor wood or kapur—*Dryobalanops aromatica*.

Further tests on a range of samples of iroko (mvule) from Uganda have confirmed the results of previous tests which showed this timber to be highly resistant to decay and almost immune to the fungi which cause dry rot. No difference in durability could be detected in timber from male and female trees, and the wood cut from dead trees also appeared to be equally resistant.

A short paper has been published[1] describing a method for determining the presence in wood of water soluble materials toxic to wood-destroying fungi.

[1] Ernest, E. C. M. A Test for the Presence of Natural Preservative Substances in Wood. *Forestry*, 1936, **10**, 58–64.

Fungal Staining of Paint Films

A further series of tests on the liability of various paint films to develop mould growth has been carried out on samples prepared by the Building Research Station. It has been found that zinc oxide paints, though not completely immune, are much less liable to mould than white lead paints. The effect of different types of oil on the susceptibility of the paint films to mould attack is now being studied, and further tests will be undertaken on standard white lead paints in which various antiseptics have been incorporated.

A simple method has been devised for testing the fungicidal efficiency of paints, in which the fungus is cultivated on small round mats made of wood pulp and soaked in malt extract, the paint being applied when the mats are overgrown with the growth of the mould. Observations are made as to whether the mould is able to penetrate the paint film and so become evident on the surface.

Dry Rot Investigations

The results so far obtained with the different types of floor laid in the experimental house have been described in a Forest Products Research Record, which is now in the press.[1] The solid floor, which was laid according to the method therein described, has remained perfectly dry and sound although dry rot infection has been artificially introduced.

[1] FINDLAY, W. P. K. Dry Rot Investigations in an Experimental House. *For. Prod. Res. Rec.*, 1936, No. **14.**

Fungal Staining of Timber

Further laboratory tests both in agar medium and on wood blocks have been carried out on various antiseptics for the control of staining fungi. Some of these antiseptics have been prepared with the kind co-operation of the Director of Chemical Research.

Larger scale tests have also been made on planks of freshly felled and cut timber which were, after treatment, placed in a kiln at 95 per cent. relative humidity and a temperature of 27° C. It was found that under these conditions rapid and severe staining soon developed on the untreated boards, which became heavily stained and very mouldy after about four weeks. In one such experiment the relative liability to stain of Scots pine and of spruce was examined, when it was found that whereas the pine sapwood quickly became stained a dark blue grey, the spruce only showed a very slight staining. The reason for this difference is not yet known.

The field experiment referred to in last year's report shows conclusively that perfectly clean pine sapwood can be obtained if the planks are dipped in a solution of an effective antiseptic immediately after felling, and are then stacked properly so that the timber can dry out and season in the normal way. The results of this test, which will shortly be published, show that there are several highly

effective proprietary antiseptics, both of the organic mercurial type and of the chlorinated phenol type, but that soda which used to be employed to some extent is practically valueless. Further similar tests on a practical scale are in progress.

Since staining fungi are supposed to derive their nourishment from the contents of the parenchyma cells in the medullary rays removal of these contents by respiration or by leaching should reduce the susceptibility of the wood to stain. It has, therefore, been suggested that wood which has been stored under water is less liable to stain than air-dried. An experiment has been started in which sticks of pine sapwood have been submerged in the log pond, where they will be kept for 6 and 12 months, and the liability to stain of samples cut from them will then be compared with those prepared from sticks which were rapidly dried in the air. Samples of sawdust made from freshly felled pine sapwood have been extracted with hot and with cold water, and then infected in the laboratory with the spores of a blue staining fungus. It was observed that after one month staining occurred in the control samples which had not been leached, and in the samples which had been extracted with cold water, but not in those extracted with hot water. The results of this preliminary experiment indicate that extraction with cold water does not prevent development of fungi which cause stain, but that hot water extraction at any rate delays it.

A further comprehensive laboratory test on a large number of naturally stained samples is in progress to try to establish definitely whether blue stain renders wood more liable to attack by the fungi which cause dry rot. So far the indications are that the presence of the stain may slightly increase the rate of decay of the wood by certain wood-rotting fungi.

The leaflet describing the various stains produced by fungi in wood and the measures for their control has now been published.[1]

[1] Sapstain in Timber. Its Cause, Recognition and Prevention. *Leafl. For. Prod. Res.*, 1936, No. **12.**

Physiological Studies of Wood-destroying Fungi

The study of the conditions which influence the fructification of Basidiomycetes in culture has been continued. A number of species have been grown on a wide range of media, including the standard malt agar and agars containing dextrose as the source of carbohydrate in different concentrations and a number of various nitrogenous materials including peptone, extracts of yeast, beef, liver, egg, " Marmite ", etc. A very satisfactory medium on which good growth and fructifications were obtained is an agar containing 2 per cent. dextrose and 1 per cent. peptone. Some species will grow on media containing up to 10 per cent. peptone. Vigorous growth and well developed fructifications occur on sterilized wheat or oat grains which have been soaked and allowed to germinate

before autoclaving. The general conclusion from this work has been that, though the natural concentration of the carbohydrate and organic nitrogen food materials in the substrate may greatly affect the size of the sporophores and the time at which they develop, it does not within wide limits determine their appearance. In other words some species, such as *Collybia velutipes*, *Schizophyllum commune* and *Armillaria mucida*, will form fruit bodies almost regardless of the medium on which they are grown, others, like *Armillaria mellea* and many species of *Fomes*, remain persistently sterile whatever medium they may be grown upon. It appears now that the failure of many wood-destroying fungi to form fruit bodies in culture is not due to any deficiency in *primary* food materials and that possibly it is necessary for fungi to build up certain substances before fructification is possible, and that some species can only do this very slowly. In order to test the effect of such substances extracted from other fungi, autoclaved extracts of fruit bodies and of yeast were added to a nutrient agar, but no significant effects were observed. It is quite probable that the hypothetical fructification-promoting substances are not heat stable. Work along this line is to be continued.

The influence of certain physical factors on fructification is also being studied. It has sometimes been stated that exposure to cold stimulates fruiting, but no evidence for this has yet been found. In a preliminary experiment cultures were exposed to a temperature of 0° C. for varying periods at different stages of growth, and then kept in the light in a warm room, but no appreciable effects were observed.

The optimum length of daily exposure to light for the vegetative growth and fructification of various species has been determined for several fungi. It has been found for certain species that this is dependent on the concentration of nutrients in the medium. On a poor medium it was found that a species of *Polyporus* (*Xanthrochrous* section) which had been isolated from tea roots could tolerate only short exposures to light. Some fungi are extremely sensitive to very short periods of exposure to even subdued light, and when studying the growth of such species under dark conditions it is essential never to bring them into daylight for even momentary examination. A simple new method for testing the effect of light of different colours on growth and fruiting has been devised. This method could also be used for varying the relative humidity over the culture, a factor that appears to have a considerable influence on the development of sporophores. Frequently more than one species of fungus may be found in the same piece of wood, and the behaviour of different mycelia towards each varies considerably, so a method has been devised which enables this to be demonstrated. Opposite ends of an open-ended glass tube $\frac{3}{4}$ in. in diameter, packed with soaked grains of wheat, are inoculated with different fungi which grow towards each other;

sometimes there is no dividing line, but in other cases a definite dark hyphal zone line may be formed or an area may be left uncovered by mycelium, owing to the inhibiting effects which the mycelia have on each other.

The water-absorbing pressure of the sporophores of a number of species of Agaricaceæ has been determined by a simple method by which it was found that, in most species, this lies between 11 and 35 atmospheres, and a paper describing these results has been prepared for publication.

The Action of Aqueous Ammonia on Wood Substance

In continuation of the study of the action of aqueous ammonia on wood substance it has been found that, in hardwoods, the extent of decomposition is more dependent on the concentration of the reagent than is the case with softwoods. There are indications that this may be explained by constitutional differences between the lignin components of the two classes of wood.

The Sampling of Wood for Chemical Analysis

Recent work by the staff of the Australian Division of Forest Products[1] has focussed attention on the important question of the sampling of wood for chemical analysis.

A general recommendation has been made that, in order to obtain the most satisfactory results, the entire sample of wood should be ground to pass a 100-mesh screen before analysis. Hitherto it has been considered satisfactory to convert a sample of wood to sawdust and to select for analysis that portion of the dust which passes an 80-mesh and is retained by a 100-mesh screen. In many cases even the 60–80-mesh material has been used. As a result of a detailed investigation with jarrah wood (*Eucalyptus marginata*) the conclusion has been reached in this Laboratory that it is undesirable to grind wood which is to be analysed to a very fine state of division, and that in general it is not possible to improve on the current practice of selecting either the 80–100 or the 60–80-mesh fraction of a sample of sawdust.

[1] Cohen, W. E., and Dadswell, H. E. The Chemistry of Australian Timbers. Part 1. A Study of the Lignin Determination. *Pamphl. Coun. sci. industr. Res. Aust.*, 1931, No. **22**.

Cohen, W. E., The Chemistry of Australian Timbers. Part 4. A Study of the Lignin Determination II. *Loc. cit.*, 1934, No. **51**.

Cohen, W. E., The Chemistry of Australian Timbers. Part 5. A Study of the Lignin Determination III. *Loc. cit.*, 1936, No. **62**.

The Hemicelluloses of Oak Wood

Fractionation of Hemicellulose A

The presence of anhydro-glucose residues in hemicellulose A of oak wood has been confirmed. They account for approximately 10 per cent. of the sapwood product, but only 1–2 per cent. of the heartwood product. Additional evidence is therefore forthcoming

that the transition from sapwood to heartwood is marked by constitutional changes in hemicellulose A.

Hemicellulose A has been split up into simpler units by two different methods: (1) by hydrolising with takadiastase under controlled conditions, and (2) by digestion with water at 100° C. In the former case the fractions consisted of an insoluble polysaccharide, a soluble polysaccharide, and the simple sugar glucose. In the latter case only two polysaccharides were obtained, one of which was insoluble and the other soluble in water. No reducing sugars were formed. The insoluble polysaccharide gave the blue coloration with iodine which characterised the original hemicellulose. It is therefore indicated that anhydro-glucose residues form an integral part of hemicellulose A in addition to anhydroxylose and uronic anhydride residues. A paper embodying the results of this work has been submitted for publication.[1]

[1] O'Dwyer, M. H. The Hemicelluloses of the Wood of English Oak. III. The Fractionation of Hemicellulose A. *Biochem. J.*, 1937, **31**, 254-257.

The Analytical Estimation of Pentosans in Wood

Since the pentosans of wood cannot be determined directly they are usually estimated from the amount of furfural obtained on distilling a weighed sample of wood with 12 per cent. hydrochloric acid under standard conditions. The furfural can be estimated titrimetrically or, alternatively, it can be precipitated with some reagent with which it forms an insoluble compound and this latter weighed. The precipitant ordinarily employed is phloroglucinol.

It has been claimed in various quarters that, on distillation with 12 per cent. hydrochloric acid, woods yield variable amounts of hydroxymethylfurfural in addition to furfural. Only the latter is derived from the true pentosans, but the former also forms an insoluble compound with phloroglucinol, and thus leads to artificially high results in pentosan estimations. In order to overcome this difficulty precipitants have been suggested which are known to combine quantitatively with furfural, but to form no insoluble compound with hydroxymethylfurfural. Chief among these alternative precipitants are barbituric acid, thiobarbituric acid, and the diphenyl derivative of the latter. From an investigation carried out during the year under review the following general conclusions bearing directly on the pentosan estimation can be made.

In the first place, during the distillation with 12 per cent. hydrochloric acid, formation of hydroxymethylfurfural is only appreciable in the case of gymnospermous woods. This implies that whereas precipitation with phloroglucinol gives reliable results for the furfural obtained from angiospermous woods it gives unreliable results with gymnospermous woods. Contrary to expectation the difficulty experienced with the latter class of wood is not overcome by using thiobarbituric acid as a precipitant. The precipitate formed by combination of this reagent with furfural

in the presence of hydroxymethylfurfural is readily peptised during washing with water, and cannot be collected quantitatively. For reasons which have not yet been determined reliable results cannot be obtained when diphenylthiobarbituric acid is used as a precipitant either. Up to the present the most satisfactory method of obviating the difficulties introduced by the presence of hydroxymethylfurfural is to redistil the original distillate. During this process hydroxymethylfurfural is destroyed and furfural can thereafter be determined quantitatively by precipitation with phloroglucinol after correcting for the unavoidable small loss which takes place during the distillation. The results of this investigation are being prepared for publication.

Utilization of Home-grown Timbers

(*a*) *Box-making*

Finding an outlet for comparatively small sized softwood timber of low grade continues to be one of the most important utilization problems. Trials of home-grown Sitka spruce from different localities to determine its suitability for the box and packing case trade have been in progress for some time past, and during 1936 two further consignments were examined from this point of view. Trees were received from Northern Ireland and others from Cockle Park, Durham. These were converted and after detailed recordings of growth rate, knottiness and other factors, material of suitable size was forwarded to a London box-making firm for a commercial trial. At the same time material carried over from previous consignments, and now considered to be fully seasoned and matured, was sent for further trial to determine the effect of prolonged storage on the workability in mass production machines. A commercial report is expected some time in 1937.

(*b*) *Wood Paving*

Preliminary arrangements for a trial of paving blocks of home-grown Scots pine in one of the London Borough streets were made in 1935, but as this investigation has since been handed over to the National Home-grown Timber Council, no Laboratory work has been done in this connection during the year under review.

(*c*) *Pulping of Home-grown Norway Spruce*

In collaboration with the Forestry Commission and, to a lesser extent, a firm of pulp manufacturers, a report was prepared on spruce from eight different localities as a possible source of raw material for groundwood pulp. The general conclusions arrived at were that under present conditions the pulp market is so well supplied with high grade pulp logs of foreign origin that manufacturers are not prepared to consider the home-grown material as suitable. There are indications, however, that if for any reason supplies of

the former were not forthcoming or not so easily and cheaply obtainable, the home-grown spruce would be suitable for pulping. This surmise is borne out by the opinion of an American authority on pulp, who declared the average run of European pulp wood to be far superior to that normally used with every satisfaction in the United States.

Investigation into the Effect of Pruning on the Quality of Timber

It becomes increasingly evident that one of the chief factors, if not the chief factor, militating against the wider use of home-grown coniferous timbers is the excessively knotty character of trees grown under plantation conditions in this country. The climate of Great Britain and economic and silvicultural conditions make it impossible to grow softwoods having the same freedom from knots as those grown in the natural and often virgin forests of Northern Europe and America, unless the quality of our timber is improved by artificial pruning.

The technique and possibilities of artificial pruning are therefore receiving the close attention of foresters—not only in this country but on the Continent and in the U.S.A. The Laboratory is concerning itself with the results of pruning as they affect timber, and to this end a great many pruned and unpruned trees have been opened up and examined to discover what has happened after the pruning, whether the pruning was correctly carried out, if not, whether the method was at fault or the operation too late in being carried out, and also, to forecast the probable improvement in the quality of the timber and consequent increase in its value for the various species according to the intensity of the pruning and the age at which it is done.

During 1936 eleven consignments of logs including Scots pine, Norway spruce, Sitka spruce, Corsican pine, oak and ash, were dealt with under the pruning programme, and reports have been produced on six of these consignments. Further supplies of material have been arranged for, and will be dealt with in 1937. In this work close touch is maintained with the Forestry Commission, which is engaged in a comprehensive investigation into the silvicultural aspects of pruning.

The Grading of Empire Timber

Grading studies on a consignment of British Honduras pitch pine, *Pinus caribæa*, supplied by the Conservator of Forests, British Honduras, were carried out with a view to determining the relative yield and quality of this timber comparable with the pitch pine of United States origin, the timber being graded in accordance with the Grading Rules for Southern Pine issued by the Southern Pine Association, U.S.A.

The Grading Rules for Empire Hardwoods were applied to the following consignments of timber dealt with during the year :—

(*a*) *Guarea cedrata* } supplied by the Forest Department,
(*b*) *Guarea thompsonii* } Nigeria.
(*c*) *Pterocarpus angolensis*, mninga, supplied by the Forest Department, Tanganyika.

The results of the grading studies on the consignments of mfumbi (*Entandrophragma utile*) and mukusu (*Entandrophragma angolense*), before and after seasoning, show that both timbers possess relatively poor standing qualities for use in the solid form, particularly the latter timber, which developed considerable distortion in drying.

Exudation of Gum from Cigar-box Cedar

A note on this investigation, which was referred to in last year's report, has been prepared, suggestions for preventative treatment being given.

Further work on this problem will be carried out.

Plywood Products

(*a*) *Survey of the Industry*

A survey of laminated wood products covering the more important phases of the manufacture of composite wood in its various forms is now in hand. The result of a number of visits to manufacturers and users of this class of product shows the desirability of extensive investigations into all branches of the manufacture and use. The dependence of this country on foreign supplies of raw material and finished product calls for very early attention and is a matter of national importance which fully justifies a definite and extensive programme of research by this Laboratory. The survey will be completed in 1937. Recent research by Continental countries into the manufacture of synthetic resin adhesives and the impregnation and compression of laminated wood products has resulted in a very considerable improvement in their quality and utility and in their wider application, to the advantage of the foreign producer. The interest shown by British manufacturers and users and their hearty co-operation in supplying information and advice in connection with this survey shows their appreciation of its object and possibilities.

(*b*) *Tests of Plywood and Glues*

The demand for tests of plywoods and adhesives is increasing. A number of tensile and compressive tests on plywood have been made by request in addition to the usual tests for glue strength as given in the British Standards Specifications.

(*c*) *The Differentiation of Glues in Plywood by Means of the Microscope*

The examination of commercial plywood samples has shown that microscopical methods may be usefully employed in the identification of different kinds of glue. From the investigation

of a limited amount of material it has been found that casein and blood albumin can be differentiated by their natural colour, their microscopic structure and their optical properties. Staining reactions have also proved useful for distinguishing between these two types of adhesive.[1]

[1] RENDLE, B. J. and FRANKLIN, G. L. A Note on the Differentiation of Casein and Blood Albumin Glues in Plywood by means of the Microscope. *J. Soc. chem. Ind., Lond.*, 1936, **15**, 105T–106T.

Charcoal and Wood-waste Utilization

The number of enquiries regarding the manufacture and use of charcoal and charcoal gas has further increased during the year.

Co-operation with the National Home-grown Timber Council, and the Home-grown Timber Marketing Association in connection with the uses and production of charcoal from British woodlands has been maintained. Numerous enquiries concerning the design of portable kilns have been dealt with. At the request of the National Home-grown Timber Council a schedule of trials for this type of kiln was prepared and supervised field trials covering a twelve-day period of operation were carried out on behalf of a portable kiln manufacturer on a fee basis.

A study of the various types of portable charcoal kilns has been made and notes on the relative merits of the different types now in use have been prepared.

Charcoal and Gazogenes

At the close of the year work was begun on the collection and sifting of existing information on gazogenes, as it is considered that the use of wood or charcoal gas may be important in times of national emergency. The possible use of charcoal gas in gazogenes as a petrol substitute has resulted in a number of enquiries which have been dealt with during the year.

Silo Construction

Information on the construction and use of wooden silos has been collected with a view to such being in demand in a case of national emergency involving the conservation and storage of home-grown vegetable products.

Photographic Work

The records of the work of the Photography Section show a slight reduction in the quantity of negatives made, but an increase of 2,300 in prints as compared with 1935.

Cinematography has played an important part in the year's programme. Twenty-three complete films have been made for this and other stations under the control of the Department. Films have been prepared and exhibited at the Chemical Engineering Plant Exhibition, Building Exhibition, Public Health Exhibition

and the Physical Society's Exhibition. The making of these films has involved visits to Glasgow, Manchester, Huddersfield, Derby, Chelmsford, Teddington, Watford and Greenwich.

New lighting equipment for obtaining a cold light beam for photomicrography has been designed in the Section and made in the Laboratory's workshops, and has proved very satisfactory in service.

An attachment enabling the cinematograph camera to be used in conjunction with the micro-photographic apparatus has also been designed in the Section and made in the Laboratory's workshop.

The original second-hand projector, employed when cinematography was first undertaken at the Laboratory, became redundant, and has now been modified to serve as an editing machine, and has proved of great value in the work.

Investigation into the possibilities of sound films is now proceeding.

Publications and Records

The card index of trade and vernacular names of timbers has been increased, 5,720 names having been referenced during the year. The index now contains a total of 37,280 names, of which 27,100 are trade and vernacular ones, and 10,180 botanical.

Eight new numbers of the Forest Products Research Records were issued during the year, as well as two new leaflets and a revised edition of Leaflet No. 4, " The Death-Watch Beetle." Other new Stationery Office publications include a monograph on " The Principal Rots of English Oak " and " A Handbook of Home-grown Timbers "(1937). The handbook incorporates most of the information contained in " The Uses of Home-grown Timbers," now out of print, together with some new data that have accumulated since the latter was issued in 1929. Details of these publications and of the various papers published in the scientific and technical press may be found in Appendix III.

In addition to the above thirty-eight miscellaneous and progress reports were prepared during the year.

The work of classifying and listing the Laboratory's collection of lantern slides, to the number of approximately 900, has been completed.

III. ADVISORY WORK

Wood Structure

The steady annual increase in the amount of advisory work under this head has been maintained. This branch of work has proved to be of mutual benefit, for besides being of obvious assistance to enquirers it serves to keep the Laboratory Staff in touch with the industrial world, and provides a useful indication of the type of problem which confronts the timber user.

Seasoning and Wood Bending

There was a further increase in the number of enquiries pertaining to seasoning and wood bending during the year under review. Of the 520 enquiries received over 85 per cent. were from trade sources asking for advice and assistance in practical problems connected with kilns, drying, bending and the moisture relations of timber.

On two occasions during the year junior officers were loaned to commercial firms to assist them in the efficient operation of the drying kilns. Representatives of nine commercial firms have attended at the Laboratory for courses of instruction in kiln operation and the principles of seasoning.

Timber Mechanics

A considerable volume of advisory work has been undertaken during the year relating to the strength properties of timber and allied products. The information requested covered such matters as suitability of timber for specific purposes from the point of view of strength properties, the substitution of one timber for another, the design of timber components and structures, the reasons for breakages which have occurred in timber components, and the influence of various factors on the strength of timber. Experimental work carried out upon request included tests for firms in this country of a number of species of foreign timbers for which strength data were not available, an investigation of the relative strength properties of a new form of fire-resisting wall board, strength tests of timber for aircraft, tests of furniture components, endurance tests to determine the efficacy of a method of baling crushed bamboo, and adhesion tests of plywood and glued joints generally. As mentioned elsewhere in this report a large volume of test work on containers has also been undertaken.

Woodworking

There has been an increase in the number of enquiries relating to timber conversion and woodworking received during the period under review. Advice has been sought on sawmilling equipment and woodworking machinery suitable for special purposes, the design and correct conditions for use of circular ripping and cross-cutting saws and bandsaws, pruning and bow saws, saw and cutter maintenance, methods of improving machine finish, the geometrical development of the profiles of cutters for tenoning machines and for automatic lathes, and other machining problems. Information has been given concerning the working qualities of a number of timbers and their suitability for specific purposes, the utilization of sawdust and wood chips, means of improving the efficiency of the machines in a joinery works, and on woodworking test technique and the apparatus employed.

Wood Preservation

The amount of work arising from applications for advice continues to show an increase. Enquiries have concerned methods of treatment and the choice of preservatives for particular purposes.

Entomology

A further increase in the advisory work of this section has been recorded during 1936, when 574 enquiries were dealt with by letter and 22 inspections of buildings carried out. The majority of the enquiries were from private individuals seeking advice on control of the Common Furniture Beetle, architects and church authorities on the Death-watch Beetle, and timber merchants and furniture manufacturers on the Powder-post Beetle. There has been a steady demand for the leaflets dealing with these three insects.

Mycology

The number of outside enquiries dealt with by the Mycology Section showed an increase over the previous year, and a larger percentage of these necessitated visits of inspection. As in previous years the majority of the enquiries concerned decay of timber in buildings and means for its prevention and cure. The advice of the section officers has also been sought on a number of occasions where there has been a difference of opinion concerning the probable cause of deterioration in cargoes of imported timber. A number of tests on wood preservatives and on materials for the control of sap stain have also been made at the request of manufacturers. The Section has co-operated with the mycologists at the Imperial Forestry Institute, Oxford, in identifying numerous cultures of fungi isolated from conifers affected by heart rot.

Among interesting cases reported to the Laboratory was one of decay of a floor, which had been caused by *Fomes roseus*, a fungus which is rare in this country, and was probably present in the timber when it was imported. An extensive case of decay in oak in a building near Cambridge was found to be caused by *Phellinus cryptarum*, a fungus which has now been reported from buildings in several parts of the country, but has not yet been found in the field.

Timber Industry

The number and diverse range of technical enquiries connected with all branches of the wood-supplying and -consuming industries and allied trades dealt with during the year has constituted a considerable part of the work of this section.

Representation on Outside Committees

The Laboratory is represented on the following Committees :—

Standing Committee on Empire Forestry—

(*Representative :* Mr. W. A. Robertson).

Empire Forestry Association—

Governing Council
(*Representative :* Mr. W. A. Robertson).

Trade Names Committee
(*Representatives :* Mr. W. A. Robertson and Mr. B. J. Rendle).

Publications Committee
(*Representatives :* Mr. W. A. Robertson and Mr. H. A. Cox).

British Standards Institution—

Technical Committee AC/2, Timber (Aircraft)
(*Representative :* Mr. C. J. Chaplin).

Technical Committee AC/3, Plywood
(*Representative :* Mr. C. J. Chaplin).

Technical Committeee B/10, Standard Definitions and Tests for Fire Resistance and Incombustibility
(*Representative :* Mr. N. A. Richardson).

Technical Committee B/14, Joinery
(*Representative :* Mr. C. J. Chaplin).

Technical Committee B/24 on Timber
(*Representative :* Mr. C. J. Chaplin).

Sub-Committee B/11/1 (Drafting) Commercial Plywoods
(*Representative :* Mr. H. E. Kinns).

Sub-Commitee B/24/1 on Softwood Grading
(*Representative :* Mr. C. J. Chaplin).

Sub-Committee B/24/2, Methods of Testing Small Clear Specimens of Timber
(*Representative :* Mr. C. J. Chaplin).

Sub-Committee B/24/3 on Hardwood Grading
(*Representative :* Mr. C. J. Chaplin).

Sub-Committee C/10/2, Fungal Restraint by Antiseptic Substances
(*Representative :* Mr. K. St. G. Cartwright).

Panel C/10/2.1, Tests on Toxicity of Wood Preservatives
(*Representative :* Mr. K. St. G. Cartwright).

Technical Committee C/15 on Glues
(*Representative :* Miss C. B. Pettifor).

Sub-Committee EL/17/2 on Poles, Brackets, etc.
(*Representative :* Mr. J. Latham).

British Wood Preserving Association—
(*Member of Council :* Mr. W. A. Robertson).

National Home-grown Timber Council—
(*Member of the Council :* Mr. W. A. Robertson).

Timber Development Association—
(*Member of Council :* Mr. H. A. Cox).
Public Relations Committee
(*Representative :* Mr. H. A. Cox).

Forestry Commission—
Advisory Committee on Forestry Research
(*Representative :* Mr. W. A. Robertson).
Home-grown Timbers Committee
(*Representative :* Mr. W. A. Robertson).

City of London College—
Timber Trades Advisory Committee
(*Representative :* Mr. W. A. Robertson).

City and Guilds of London Institute—
Advisory Committee on Woodcutting Machinists' Work
(*Representative :* Mr. P. Harris).

International Association for Testing Materials—
British Committee
(*Representative :* Mr. C. J. Chaplin).
Commission on Mechanical Testing of Timber
(*Representative :* Mr. C. J. Chaplin).

IV. WORK FOR THE EMPIRE OVERSEAS

Particulars of work carried out for the units of Empire overseas are found in Appendix II, the Second Annual Report of the Standing Conference on Timber Utilization.

APPENDIX I.

STAFF AT THE FOREST PRODUCTS RESEARCH LABORATORY

Director of Forest Products Research : W. A. Robertson.
Principal Scientific Officer : S. T. C. Stillwell, B.Sc.
Scientific Field Assistant : A. N. David, Dip.For.
Clerk (Higher Grade) : L. Forbes.
Assistant, II : W. R. Hutchins.

Section of Timber Industry

Scientific Officers : H. A. Cox, M.A., Dip.For., Dip.Tim.Tech.; P. Harris, B.Sc.
Assistant, I : H. E. Kinns.
Assistant, II : G. H. Donald, B.A.
Assistant, III : H. J. Endersby.

Section of Wood Structure

Officer in Charge : B. J. Rendle, B.Sc., A.R.C.S.
Scientific Officer : S. H. Clarke, M.Sc.
Junior Scientific Officer : E. W. J. Phillips, B.Sc., A.R.C.S.
Assistant, III : C. L. Stocker, B.A., Dip.For.

Section of Timber Physics

Officer in Charge : W. W. Barkas, M.Sc.
Scientific Officer : E. D. van Rest, B.A., B.Sc., F.S.S.
Assistant, III : R. F. S. Hearmon.

Section of Seasoning

Officer in Charge : R. G. Bateson, B.A.
Scientific Officers : R. A. G. Knight, B.Sc., A.M.I.Mech.E.; W. C. Stevens, M.A., A.M.I.Mech.E.
Assistants, III : A. R. Dean, R. E. Hodge, D. D. Johnston, R. J. Newall, G. H. Pratt, N. Turner.

Section of Timber Mechanics

Officer in Charge : C. J. Chaplin, M.Sc., M.E.I.C., M.I.Mech.E.
Scientific Officers : F. H. Armstrong, M.Sc., A.M.I.Mech.E.; J. Latham, B.Sc.; E. H. Nevard, B.Sc.(Eng.), D.K.C.; Miss C. B. Pettifor, B.Sc.
Junior Scientific Officer : H. Q. Golder, M.Eng.
Assistant, II : A. J. Foord.
Assistant, III : F. L. Arney.

Section of Wood Preservation

Officer in Charge : J. Bryan, M.Eng., A.M.Inst.C.E.
Scientific Officer : N. A. Richardson, B.Sc., A.I.C.
Assistants, III : L. S. Doman, D. N. Smith.

Section of Entomology

Officer in Charge : R. C. Fisher, B.Sc., Ph.D.
Scientific Officers : F. R. Cann, D.I.C.; E. A. Parkin, M.Sc., Ph.D., D.I.C.
Assistant, III : E. C. Harris.

SECTION OF MYCOLOGY

Officer in Charge : K. St. G. Cartwright, M.A., D.I.C., F.L.S.
Scientific Officer : W. P. K. Findlay, M.Sc., A.R.C.S., D.I.C.
Assistants, III : E. C. Badcock; Miss E. C. M. Ernest, B.Sc., Ph.D., D.I.C.

SECTION OF WOOD CHEMISTRY

Officer in Charge : W. G. Campbell, B.Sc., M.S.
Scientific Officer : Miss M. H. O'Dwyer, B.Sc., Ph.D., D.I.C.
Junior Scientific Officers : S. A. Bryant, B.A.; G. Swann, B.Sc., Ph.D.
Assistant III : D. F. Packman.

SECTION OF PUBLICATIONS AND RECORDS

Officer in Charge : C. J. N. McCracken, B.A., Dip.For.
Assistant, III : Miss M. B. Hyde, M.Sc.

On 31st December, 1936, the Staff of the Laboratory numbered 138.

APPENDIX II

STANDING CONFERENCE ON TIMBER UTILIZATION.

*REPORT OF THE STANDING CONFERENCE FOR THE YEAR ENDED 31st DECEMBER, 1936

During the year the Conference has been strengthened by the appointments of representatives of the Government of Canada and Southern Rhodesia. The meetings of the Conference continue to provide opportunities for the discussion of matters of common interest concerning the development of the forest resources of the Empire, the investigation of the properties of new or little known species and other factors incidental to the exploitation of Empire timbers generally.

Meetings and Business Done

The Conference met at 16, Old Queen Street, Westminster, on two occasions during the year. At both meetings the Chair was occupied by Sir John Stirling Maxwell, Bart., K.T., and there was a reasonably good attendance Several absences were recorded at the first meeting, however, owing to certain representatives being on duty overseas.

At the Fifth Meeting, held on Thursday, 5th March, 1936, the Chairman welcomed the two newly-appointed representatives of the Government of Canada. The draft of the Second Annual Report of the Conference, covering the work for 1935, was considered and approved. Reports from the Department of Scientific and Industrial Research were received, and certain questions relating to the species under test at the Department's Forest Products Research Laboratory were answered by the Director of Forest Products Research. The attention of the Conference was drawn to a recent advance in the freight rates on timber from Singapore and the Conference agreed that the matter should be brought to the notice of the Colonial Office so that the Shipping Conference might be approached through the appropriate channels with regard to the apparent discrimination against Malayan timbers. Reference was made to the approaching Imperial Scientific Conference and it was agreed that, if opportunity offered, representatives from the various units of the Empire overseas should be invited to meet the Conference to discuss further possible ways of developing the forest resources of the Empire and of increasing the sale of Empire timbers.

The Sixth Meeting was held on Thursday, 8th October and reports by the Department of Scientific and Industrial Research were received. Several questions arising out of the report on the progress of investigations of Empire timbers at the Forest Product Research Laboratory were answered by the Director of Forest Products Research. The report included an account of the steps which had been taken to give effect to the recommendation of the Conference to the Colonial Office arising from the advance in the freight rates on timbers from Malaya, and, after a full discussion of the situation and after hearing a statement from a representative of the Colonial Forest Resources Development Department, the Conference agreed to recommend that members of the Conference having special knowledge pertaining to the matter should place all the facts in their possession at the disposal of the Colonial Forest Resources Development Department, with a view to a further approach to the Shipping Conference.

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* Being a report prepared by the Conference under Standing Order No. 9, which provides for the submission annually to the co-ordinating bodies of an Annual Report on the proceedings of the Conference. (See page 67.)

The Conference considered a statement by the Director of Forest Products Research concerning the proposed publication of a handbook dealing with Empire timbers to take the place of the Handbook of Empire Timbers issued by the Empire Marketing Board in 1932, the remaining stocks of which were rapidly becoming exhausted. It was agreed that a book on Empire timbers was necessary and that it was advisable that a new publication should be ready as soon as possible, in order to avoid any difficulties which might arise if a considerable period were to elapse between the exhaustion of the remaining stocks of the old publication and the completion of the new one. A discussion on the information which could be conveniently included in the new handbook followed, in the course of which it was made clear that the Department of Scientific and Industrial Research would not be responsible for any information which did not emanate from the Forest Products Research Laboratory. If information from other sources were included it should be made clearly apparent from what sources such information had been obtained. The Conference recommended that the offer of the services of certain representatives of the Imperial Institute and the Department be accepted to consider the proposed list of species and to assist in determining which species were worthy of inclusion.

REPORT BY THE DEPARTMENT TO THE CONFERENCE ON THE INVESTIGATION OF EMPIRE TIMBERS FOR THE YEAR ENDED 31ST DECEMBER, 1936

The various sections of the Forest Products Research Laboratory engaged in the investigation of the properties of Empire timbers have been occupied during 1936 with a full programme of test work. The greater part of this work has been devoted to timbers from one or other of the Colonies, chiefly Nigeria, Uganda, and British Honduras, but some work has also been undertaken for the Governments of the Dominions of New Zealand and the Union of South Africa.

A brief account of the progress made during 1936 in the various investigations will be found under the heading " Progress of Investigations " on page 62. That the interest in Empire timbers is still being maintained is proved by the number of enquiries concerning them which have been dealt with by officers of the Laboratory during the year.

Applications for Tests

No new application for tests of Colonial timbers has been received during the year, and it may therefore be anticipated that less time will be devoted to the investigation of Empire timbers at the Forest Products Research Laboratory during 1937. It will be seen from the statement on the progress of investigations that a number of tests are still in progress, but it is anticipated that most of these will be completed in the first half of the coming year. It will not be possible to complete all the investigations which are either in progress or are contemplated by the end of 1937, however, as some of the species air-season very slowly, and tests of air-seasoned material are an essential part of any major or preliminary investigation.

The High Commissioner for the Union of South Africa has made further use of the services of the Laboratory in connection with the shipment of oranges from South Africa in boxes made from timber grown in the Union. Further consignments have been inspected on arrival and it has been found that the modifications in construction suggested in the report on the earlier consignment had been adopted and that in consequence the boxes in the second consignment had withstood the shocks incidental to loading and handling in transit much more satisfactorily. A report is being prepared.

The New Zealand Government has also asked for further co-operation and assistance in the testing of butter boxes of different types. A report on this work will be ready in the near future.

Progress of Investigations

A. Investigations completed

The following investigations have been completed during 1936.

Major Scale Investigations

1. Ceylon gurjun : *Dipterocarpus zeylanicus* Thw.

The final report on the major scale tests of Ceylon gurjun was issued in June, 1936. The timber did not differ to any marked extent from the gurjun from other sources in any of its properties. A block floor of this timber has recently been laid in the library at the Forest Products Research Laboratory, and this will permit of its wearing qualities under service conditions being compared with those of the Andaman gurjun floor on the landing outside the library door. There appears to be little prospect of a surplus, available for export from Ceylon, when local demands have been met.

2. Santa Maria : *Calophyllum brasiliense* var. *rekoi* Standl., from British Honduras

The investigation of the properties of Santa Maria was completed and the report issued in February, 1936. The results of the investigation were somewhat disappointing, since they tended to show that there was very little hope of finding a market for the timber in this country at economic prices. Reports have been received from time to time that Santa Maria is used in America as a mahogany substitute. Enquiries instituted by a representative of the Imperial Institute on the Standing Conference, showed that the opinion of those in America who have had experience of the wood conforms with the statements made in the report of the tests carried out at the Forest Products Research Laboratory.

3. British Honduras pitch pine : *Pinus caribaea* Morelet

The large scale investigations of the properties of British Honduras pitch pine have now been completed. The timber has been found to resemble the pitch pine from the Southern States in many of its properties, although it is not comparable in quality with longleaf pitch pine. The sapwood was found to be very liable to develop sap stain, but this can easily be prevented at a small cost and is, therefore, unimportant. It is not anticipated that there will be a large market for the timber in this country at present, but, it is possible that as the supplies of longleaf pitch pine become exhausted a demand for this timber may arise. There are some indications that the mining industry in the Union of South Africa may absorb some of the material which is surplus to the requirements of British Honduras itself and the neighbouring islands. The investigation tends to indicate that *Pinus caribaea* is perhaps the most promising of the secondary species of the colony.

Limited Major Scale Investigation

4. Opepe : *Sarcocephalus diderrichii* de Wild., from Nigeria

The investigation of the properties of opepe has been completed. Seasoning did not present any serious difficulty, although there was a tendency towards splitting and checking, from which it is clear that care is required during the seasoning process. The wood was found to possess a high resistance to fungal decay, and therefore should prove very suitable for use in exposed situations. The strength properties were found to be comparable with those of Burma teak, except that opepe is somewhat harder, somewhat less resilient and slightly more prone to split. No particular difficulty was experienced in working the timber, but in quarter-sawn material the finish obtained in planing under ordinary commercial conditions was not entirely satisfactory. This timber is being tried for flooring. Its high resistance to decay, combined with

its strength properties, indicates that it should prove a useful addition to the class of timbers for heavy structural work under exposed conditions.

Preliminary Investigations

5. Okan : *Cylicodiscus gabunensis* Harms. from Nigeria

A report on the preliminary investigation of the properties of okan was issued in February. The results of the tests indicated that the timber kiln-seasons slowly with tendency to split and check, and to a less extent, warp. The same tendency was observed during air seasoning. The mechanical properties are of a high order comparable generally to those of greenheart, although in bending strength and stiffness it is somewhat inferior to greenheart. It was found to be unsuitable for steam bending. Its resistance to fungal decay as revealed by laboratory tests was very marked. It was difficult to work producing a perceptible dulling effect on the cutting edges of tools. Owing to the effect of interlocked grain " picking up " occurred to a very marked extent with ordinary cutting angles, but when the cutting angle was reduced to 10° or less this was largely eliminated. It turned satisfactorily, but was not suitable for ornamental turnery on the end grain.

6. Odoko : *Scottellia coriacea* A. Chev., from Nigeria

The investigation of the properties of odoko was completed in June. The timber was found to be a uniformly finely textured wood of moderate density, comparable in this respect to beech or maple. It air-seasoned and kiln-seasoned at a moderate rate but with a marked tendency to split. Little distortion took place, however, and the knots remained sound. It was not suitable for steam bending. Its mechanical properties compared with those of beech, and it was found to be amenable to impregnation treatment. The investigation of its resistance to decay showed it to be readily attacked by fungi causing " white rot " but less readily by " brown rot " fungi. No marked difficulty was met with in working the wood, either by hand or machine, the working qualities being comparable with those of sycamore. The wood should prove of considerable value in the country of origin, and prime quality material might possibly find a market in this country.

Special Investigations

7. Ekhimi : *Piptadenia africana* Hook. f., from Nigeria.

8. Ayanran : *Distemonanthus Centhamianus* Baill., from Nigeria.

A small scale investigation of the working qualities of the above-mentioned species was completed during the year and a report has recently been issued.

B. Investigations in progress on 1st January, 1936, and not yet completed

Preliminary Investigations

9. White Olivier : *Terminalia sp.*, from Trinidad.

10. Nargusta : *Terminalia sp.*, from British Honduras.

11. Cramantee : *Guarea excelsa*. H. B. K., from British Honduras.

12. Waika Chewstick : *Symphonia globulifera* L., f. from British Honduras.

13. Cypress : *Podocarpus guatemalensis* Standl., from British Honduras.

14. Timbersweet : (identity not determined) from British Honduras.

The preliminary investigations of the above were all undertaken at the same time and are now approaching completion. Some work remains to be done on air-seasoned material, but it is anticipated that reports on all these investigations will be ready for issue in the spring of 1937.

Special Investigations

15. East African pencil cedar: *Juniperus procera* Hochst. from Kenya.

The further work on the investigation of East African pencil cedar has been delayed by the necessity for devising and constructing special apparatus to measure cutability both before and after softening treatment. The apparatus has been completed, however, and the tests are now proceeding. It is possible that further material of plantation grown cedar will be sent from Tanganyika for comparison with cedar grown under natural forest conditions.

16. Queensland walnut: *Endiandra palmerstonii* C. T. White.

Further work directed towards the solution of problems connected with the working of this species has been carried out. Manufacturers of saws are co-operating, and already new types have been evolved which considerably reduce the difficulty previously met with in sawing Queensland walnut which has been dried to suitable moisture contents for interior work. The investigation has extended over a considerably longer period than was at first anticipated, but much useful information has accrued.

17. Mvule: *Chlorophora excelsa* Benth & Hook. f., from Uganda.

18. Mukusu: *Entandrophragma angolense* C.D.C., from Uganda

19. Mufumbi: *Entandrophragma utile* Sprague, from Uganda

The special investigations of certain properties of the above-mentioned timbers from Uganda are now approaching completion. It has not yet been possible, however, to finish the tests on air-seasoned material.

20. Keruing: *Dipterocarpus Baudii* Korth.

Kumus: *Shorea lævis* Ridley
Merbau: *Intsia bakeri* Prain.
Nemesu: *Shorea pauciflora King.*
Tempenis: *Sloetia sideroxylon* Teysm. & Binn.
All from Malaya.

The investigation of the working qualities of these species is being undertaken as and when the moisture content of the material which is air-seasoning is reduced to the required percentage. It is expected that the tests will be completed in 1937.

C. *Investigations begun during* 1936

Preliminary Investigations

21. Obobonekwi: *Guarea thompsonii* Sprague & Hutch.

22. Obobonufwa: *Guarea cedrata* (A. Chev.) Pellegrain, both from Nigeria

The material for preliminary investigations of the properties of the above-mentioned species of *Guarea* was received at the Laboratory early in 1936. Tests on green material and kiln-seasoning tests have been completed. Air-seasoning of part of the stock is now in progress and the remaining tests will be undertaken as soon as this stock is ready.

Special Tests

23. Meranti rambai daun: *Shorea acuminata* Dyer
Meranti temak: *Shorea hypochra* Hance
Gerutu gerutu: *Parashorea lucida* (Miq.) Kurz.
Mengkulang: *Tarrietia simplicifolia* Mast.
Damar laut merah: *Shorea kunstleri* King, from Malaya

Material for small scale tests of the working qualities of the five Malayan timbers enumerated above, has been received at the Laboratory and is now air-seasoning. It is not possible to forecast with any degree of accuracy the date when the tests will be started.

During the year addenda covering work on air-seasoned material, supplemental to reports on :—

Obeche (wawa) : *Triplochiton scleroxylon* K. Schum., from the Gold Coast.
Obeche : *Triplochiton scleroxylon*, from Nigeria
Podo : *Podocarpus gracilior* Pilg.
Podocarpus sp.
Podocarpus usambarensis Pilg.
} from East Africa
Meranti : *Shorea* sp., from Malaya
Wallaba : *Eperua falcata* Aubl., from British Guiana
Purpleheart : *Peltogyne ? pubescens* Benth., from British Guiana
Musisi : *Mæsopsis eminii* Engl., from Uganda
Mninga : *Pterocarpus angolensis* D.C., from Tanganyika, have been issued.

PRACTICAL TRIALS OF EMPIRE TIMBERS AT THE LABORATORY

A further service trial of Ceylon gurjun, *Dipterocarpus zeylanicus* Thw., in the form of block flooring has been instituted in the library. Some bookshelves of iroko (mvule), *Chlorophora excelsa* Benth. & Hook. f., from Uganda, have also been made for the library to determine what changes in colour are likely to occur in the timber after it has been made up when exposed to ordinary conditions of light and air in use, and to investigate the "working" of the timber with changes in atmospheric conditions.

APPENDIX IIA

STANDING CONFERENCE ON TIMBER UTILIZATION

CONSTITUTION

Chairman :

Sir JOHN M. STIRLING MAXWELL, Bart., K.T.

Members appointed to represent Dominions, India, Colonies, and other Units of Empire

Representing :	*Members :*
Canada	K. G. FENSOM, Esq. R. DOUGLAS ROE, Esq.
Australia	F. L. MCDOUGALL, Esq., C.M.G.
New Zealand	N. L. WRIGHT, Esq. F. H. TAYLOR, Esq.
South Africa	F. J. DU TOIT, Esq.
India	Sir HUGH WATSON.
Newfoundland	Rt. Hon. Sir FRANCIS DYKE ACLAND, Bart., M.P.
Southern Rhodesia ..	B. F. WRIGHT, Esq.

Members appointed by the Department

Nominated by :	
Colonial Office	R. V. VERNON, Esq., C.B. Major R. D. FURSE, D.S.O. Major F. M. OLIPHANT. Major J. R. COSGROVE, D.S.O., M.C.
Imperial Forestry Institute.	Professor R. S. TROUP, C.M.G., C.I.E., D.Sc., F.R.S.

Ministry of Agriculture & Fisheries, Royal Botanic Gardens, Kew.	Sir ARTHUR W. HILL, K.C.M.G., Sc.D., F.R.S.
Imperial Institute	J. P. FRASER, Esq. S. E. CHANDLER, Esq., D.Sc.
Timber Development Association.	E. H. B. BOULTON, Esq., M.C., M.A.
Department of Scientific and Industrial Research.	W. A. ROBERTSON, Esq. Director of Forest Products Research W. E. MCKEE, Esq.

APPENDIX IIB

(*Revised 10th September*, 1935.)

RULES AND STANDING ORDERS OF THE STANDING CONFERENCE ON TIMBER UTILIZATION

1. *Objects*

The Department of Scientific and Industrial Research having agreed to hold available, for the assistance of the various parts of the Empire overseas, under financial arrangements to be approved from time to time by the Department, the facilities of its Forest Products Research Laboratory at Princes Risborough for the investigation of the qualities of particular timbers (which determine their uses), and for furnishing technical information of importance in marketing such timbers, it has been decided to establish a standing conference to act as a consultative and advisory body to the Department and to the various units of the Empire overseas which desire to make use of these facilities, or to be represented on the Conference.

2. *Constitution*

Any Dominion, Colony, or other unit of the Empire overseas which makes use of these facilities or expresses a wish to be represented on the Conference will be entitled to appoint one or more representatives to membership of the Conference. The names of all representatives so appointed will be communicated to the Department by the Office of the appointing unit of Empire. The Department will appoint representatives to be members of the Conference who may include persons nominated by other Departments of State in the United Kingdom interested in the use of Empire-grown timbers, a person or persons nominated by the Minister of Agriculture and Fisheries as representing the Royal Botanic Gardens at Kew, persons nominated by the Governing Bodies of the Imperial Institute and the Imperial Forestry Institute, persons nominated by any timber trade organisation in the United Kingdom on an invitation issued on the recommendation of the Standing Conference, and persons not included in the foregoing categories who have in the past been of conspicuous service as members of the Empire Timbers Committee or otherwise, in promoting the use of Empire-grown timbers in the United Kingdom.

3. *The Year*

For the purpose of these rules and standing orders the year is understood to run from January 1st to December 31st.

4. *Chairman*

The Chairman will be appointed by the Department from among the members of the Conference as defined by its constitution as set out in 2 above. He will hold office for three years, and will be eligible for reappointment for

a further period, not exceeding three years, on the completion of a term of office.

5. *Secretarial work and place of meeting*

The Department will undertake the secretarial work of the Conference and will provide a place for its meetings.

6. *Meetings*

Two ordinary meetings of the Conference will be held in each year. A notice of the date, time and place of each ordinary meeting will be sent to each member one month before the meeting. A special meeting may be called at any time by the Chairman in his discretion, and shall be called by the Chairman on the requisition of the representative, or, if more than one, the representatives of any unit of the Empire appointing to membership of Conference, such requisition to be accompanied by notice of the question or questions to be raised at the meeting. At least one week's notice of the date, time and place of each special meeting will be sent to each member.

7. *Business*

The regulation of the business of the meetings of the Conference will be in the hands of the Chairman. A member wishing to bring any matter before a meeting of the Conference is requested to give notice to the Director, Forest Products Research Laboratory, Princes Risborough, Bucks, fourteen days before the meeting, so that the matter may be included as an item on the agenda. Matters to be so brought before the Conference would include those which bear on the marketing of any timber grown in the part of the Empire overseas which the member may represent. An agenda paper for each meeting will be circulated so as to reach members at least three days before the meeting.

8. *Presentation of Reports to the Conference*

A brief progress report on the work carried out by the Department on Empire-grown timbers under the arrangements defined in 1 above during the period since the last ordinary meeting of the Conference will be presented to the Conference at each ordinary meeting by the Department. Members representing various units of the Empire overseas or the institutions or trade organisations defined in 2 above are invited to present similarly to the Conference progress reports on any work carried out by the unit of Empire, institution or organisation they represent which appears to be of general interest in promoting the objects of the Conference. Such reports should reach the Director, Forest Products Research Laboratory, at least fourteen days before the meeting at which they are to be presented.

9. *Reports of the proceedings of the Conference*

As soon as possible after December 31st in each year the Conference will present to the bodies appointing members a report of its proceedings during the past year. These reports may be printed and published by the Department in its discretion.

APPENDIX III PUBLICATIONS

(A complete list to-date of the Laboratory's publications may be obtained on application to the Director, Forest Products Research Laboratory, Princes Risborough, Aylesbury, Bucks.)

1.—LIST OF PUBLICATIONS ISSUED DURING 1936

A.—*Stationery Office Publications*†

	Price s.	d.
Report of the Forest Products Research Board for the Year 1935 ..	2	0

RECORDS :—

No. 6.—The Properties of an African Mahogany (*Khaya anthotheca* C.DC.)	0	6
No. 7.—The Properties of Mansonia (*Mansonia altissima* A. Chev.)	0	6
No. 8.—Strength Tests of Structural Timbers. Part 2. General Procedure of selecting and testing Joists, with Data on British Columbian Douglas Fir (*Pseudotsuga dougalsii* Carr.) By C. J. Chaplin, M.Sc., M.E.I.C., M.I.Mech.E., and E. H. Nevard, B.Sc.	0	6
No. 9.—Methods of applying Wood Preservatives. Part I. Non-Pressure Methods. By J. Bryan, M.Eng., A.M.Inst.C.E.	0	6
No. 10.—The Practice of Wood Bending. By W. C. Stevens, M.A., A.M.I.Mech.E.	0	6
No. 11.—The Properties of Home-grown Oak	0	6
No. 12.—Seraya, Meranti and Lauan. By B. J. Rendle, B.Sc., A.R.C.S., and S. H. Clarke, M.Sc.	0	6
No. 13.—Types of Timber Kilns. By R. G. Bateson, B.A. ..	0	6

‡LEAFLETS :—

No. 4.—The Death-watch Beetle (Revised Edition, 1936).
No. 11.—The Hot and Cold Open Tank Process of Impregnating Timber.
No. 12.—Sap Stain in Timber. Its Cause, Recognition and Cure.

MISCELLANEOUS :—

The Principal Rots of English Oak. By K. St. G. Cartwirght, M.A., F.L.S., and W. P. K. Findlay, M.Sc., D.I.C. ..	2	0

B.—*Other Publications*§

ARMSTRONG, F. H.
The Mechanical Properties of "Blackheart" Ash Wood (*Fraxinus excelsior* L.). *Quart. J. For.*, 1936, **30,** 202–210.

BAMFORD, K. F., and CAMPBELL, W. G.
The Determination of Lignin in the Analysis of Woods. *Biochem. J.*, 1936, **30,** 419–428.

† *Obtainable from any of the Sale Offices of His Majesty's Stationery Office, LONDON : Adastral House, Kingsway, W.C.2 ; EDINBURGH :* 120 *George Street ; MANCHESTER :* 26 *York Street ; CARDIFF :* 1 *St. Andrew's Crescent ; BELFAST :* 80 *Chichester Street.*

‡ *The Leaflets are obtainable gratis from the Director, Forest Products Research Laboratory.*

§ Reprints of papers *not* marked with an asterisk are obtainable at a nominal cost from the Director, Forest Products Research Laboratory.

BAMFORD, K. F., and VAN REST, E. D.

The Relationship between Chemical Composition and Mechanical Strength in the Wood of English Ash (*Fraxinus excelsior* Linn.). *Biochem. J.*, 1936, **30,** 1849–1854.

BARKAS, W. W.

Wood-water Relationships. 1 : Molecular Sorption and Capillary Retention of Water by Sitka Spruce Wood. *Proc. phys. Soc.*, 1936, **48,** 1–17.

Wood-water Relationships, 2 : The Fibre Saturation Point of Beech Wood. *Proc. phys. Soc.*, 1936, **48,** 576–588.

BATESON, R. G.

The Shrinking and Swelling of Wood. Experiments on the Influence of Sorbitol. *Chem. Tr. J.*, 1936, **99,** 493.

CAMPBELL, W. G.

*The Chemical Reactions induced by Wood-destroying Fungi. (Paper read before the *Second International Congress for Microbiology*, 1936.)

CARTWRIGHT, K., ST. G., CAMPBELL, W. G., and ARMSTRONG, F. H.

The Effect of Progressive Decay by *Polyporus hispidus* Fr. on the Strength of English Ash (*Fraxinus excelsior* L.). *Proc. roy. Soc.* (Ser. B.), 1936, **120,** 76–95.

CHAPLIN, C. J.

The Technical Aspect of grading Baltic Timbers. *Wood*, 1936, **1,** 238–239.

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Abrasion of Floors. Testing the Relative Resistance to Wear of Flooring Timbers. *Wood*, 1936, **1,** 576–581; **2,** 79.

CLARKE, S. H.

*What Wood Structure means to the User of Timber. *Timb. News Sawm. Chron.*, 1936, **45,** 194–195.

The Influence of Cell-wall Composition on the Physical Properties of Beech Wood (*Fagus sylvatica*). *Forestry*, 1936, **10,** 143–148.

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DONALD, G. H.

*Pruning Studies at Princes Risborough. *Quart. J. For.*, 1936, **30,** 111–120.

*The Effect of Pruning on the Quality of Timber. Paper read before the *British Association*, 1936.

*How Pruning affects the Quality of Timber. *Timb. News Sawm. Chron.*, 1936, **45,** 58, 60.

ERNEST, E. C. M.

A Test for the Presence of Natural Preservative Substances in Wood. *Forestry*, 1936, **10,** 58–64.

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Influence of Certain Calcium Compounds on the Rate of Decay of Wood by Fungi. *J. Soc. chem. Ind., Lond.*, 1936, **55,** 103T–105T.

*The Prevention of Blue Stain and Mould on Timber by Chemical Dips. *Timb. News Sawm. Chron.*, 1936, **45,** No. 2022, 14, 17.

*The Prevention of Decay of Timber in Ships. *Shipbuilder*, 1936, **43,** 118.

FISHER, R. C.

The Habitat of *Anoncodes melanura* L. (*Coleoptera Oedemeridae*). *Ent. mon. Mag.*, 1936, **72,** 41–42.

Insects attacking the Timber of English Oak. *Forestry*, 1936, **10,** 45–57.

The Need for Forest Entomologists with special Reference to the Pin-hole Borer Problem. *Emp. For. J.*, 1936, **15,** 201–209.

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Uniformity of Air Conditions. *Archit. J.*, 1936, **83,** 275–276.

LATHAM, J., and FOORD, A. J.

*A New Internal Fitting for Packing Cases. *Fibre-Bd. Contain.*, 1936, **3,** 13–14.

*Improvements in the Testing of Fibreboard Containers. *Fibre-Bd. Contain.*, 1936, **3,** 16–20.

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A Study of the Food Relations of the *Lyctus* Powderpost Beetles. *Ann. appl. Biol.*, 1936, **23,** 369–400.

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*The Elements of Wood Structure. *Biology*, 1936, **2,** 244–248.

RENDLE, B. J., and FRANKLIN, G. L.

A Note on the Differentiation of Casein and Bloodalbumin Glues in Plywood by Means of the Microscope. *J. Soc. chem. Ind., Lond.*, 1936, **55,** 105T–106T.

ROBERTSON, W. A.

Timber and Shipbuilding. *Trans. Instn Engrs Shipb. Scot.*, 1936, **80,** 27–48.

STEVENS, W. C.

*The Bending of Wood. *Timb. News Sawm. Chron.*, 1936, **45,** 113–114.

Methods of Bending Wood. *Wood*, 1936, **1,** 177–179.

Bending Spade Handles. An Improved Method. *Timb. Tr. J., Annual Special Issue*, June 24th, 1936, 251–252.

*Strength of Glued Joints. Tests with Insecticide Treatment. *Timb. Tr. J.*, 1936, **138,** 573.

*Silencing High Speed Circular Saws. *Timb. Tr. J.*, 1936, **139,** 31st October, xxiii; also in *Timb. Plywood*, 1936, **71,** 1104; *Cabinet Maker*, 1936, No. **1934,** 168: *Furniture Mfr*, 1937, **7,** 233; and *Timb. News Sawm. Chron.*, 1936, **45,** 493.

The Forest Products Research Laboratory, Princes Risborough, *Timb. Plywood, Annual Special Issue*, 1936. 119/1–119/8. (Nine component articles on the work of the Laboratory by various authors.)

II.—LIST OF PUBLICATIONS ISSUED THROUGH H.M. STATIONERY OFFICE PRIOR TO 1936.

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No. 1.—The Movement of Moisture with Reference to Timber Seasoning. By S. T. C. Stillwell, B.Sc. .. (*Out of print*)		
No. 2.—Moisture Movement through Wood. The Steady State. By J. F. Martley, D.I.C., B.Sc. .. .. .. (1926)	1	3
Special Reports :—		
No. 1.—The Air-Seasoning and Conditioning of Timber. By F. M. Oliphant .. .. (1927) (*Out of print*)		
No. 2.—The Principles of Kiln-Seasoning of Timber. Part I. Types of Commercial Kilns in Use. By S. T. C. Stillwell, B.Sc. .. .. (1928)	0	9
No. 3.—Practical Kiln-Drying. By W. C. Stevens, M.A., A.M.I.Mech.E. .. .. (1933)	1	6
Bulletins :—		
No. 1.—Dry Rot in Wood. Revised edition (1933)	1	0
No. 2.—*Lyctus* Powder-post Beetles. By Ronald C. Fisher, B.Sc., Ph.D. .. .. (*Out of print*)		
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No. 6.—The Timber of Corsican Pine (*Pinus laricio* Poiret) (1930)	2	6
No. 7.—Home-grown Timbers. Their Anatomical Structure and its Relation to Physical Properties. Elm. By S. H. Clarke, B.Sc. .. .. (1930)	3	6
No. 8.—The Use of Home-grown Larch Poles for Transmission Lines .. .. (1931)	2	0
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No. 11.—The Effect of Progressive Decay by *Trametes serialis* Fr. on the Mechanical Strength of the Wood of Sitka Spruce. By K. St. G. Cartwright, M.A., W. P. K. Findlay, M.Sc., C. J. Chaplin, M.Sc., and W. G. Campbell, B.Sc., M.S.	1	6
No. 12.—Some Characteristics of Home-Grown Timbers. By C. J. Chaplin, M.Sc., M.E.I.C., J. Latham, B.Sc., and F. H. Armstrong, M.Sc., A.M.I.M.E. .. .. (1931)	2	0
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No. 14.—The Determination of the Moisture Content of Timber. By R. A. G. Knight, B.Sc. (Eng.) .. .. (1932)	1	0
No. 15.—The Timber of Home-grown Scots Pine (*Pinus sylvestris* L.) .. .. (1932)	5	0
No. 16.—A Survey of the Damage caused by Insects to Hardwood Timbers in Great Britain. By Ronald C. Fisher, B.Sc., Ph.D., F. R. Cann, D.I.C., and E. A. Parkin, B.Sc., D.I.C. .. .. (1932)	2	6

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Project 1.—Progress Report 2. Tests of some Home-grown Timbers in their Green and Seasoned Conditions. By C. J. Chaplin, M.Sc., M.E.I.C., and F. M. Mooney, B.Sc., A.M.E.I.C. (1929)	1	0
MISCELLANEOUS :—		
The Uses of Home-grown Timber .. .. (*Out of print*)		
§LEAFLETS :—		
No. 1.—" Worm " in Furniture. (*Out of print. Superseded by Leaflets Nos.* 3, 4 *and* 8.)		
No. 2.—The Influence of Certain Factors on the Kiln-Drying of Timber and on the Choice of the Types of Drying Kiln. By S. T. C. Stillwell, B.Sc. .. .. .. (*Out of print*)		
No. 3.—*Lyctus* Beetles and their Control. (*Revised edition*) (1935)		
No. 4.—The Death-watch Beetle. (*Revised edition*) .. (1933)		
No. 5.—Empire Timbers from Home and Overseas for Building and Structural Purposes. By Major J. R. Cosgrove, D.S.O., M.C., M.E.I.C. .. .. (1932)	1	3
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§ The Leaflets (except No. 5) are obtainable from the Director, Forest Products Research Laboratory.

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